

ARTIFICIAL FIREWORKS - JONES - LONDON, 1776





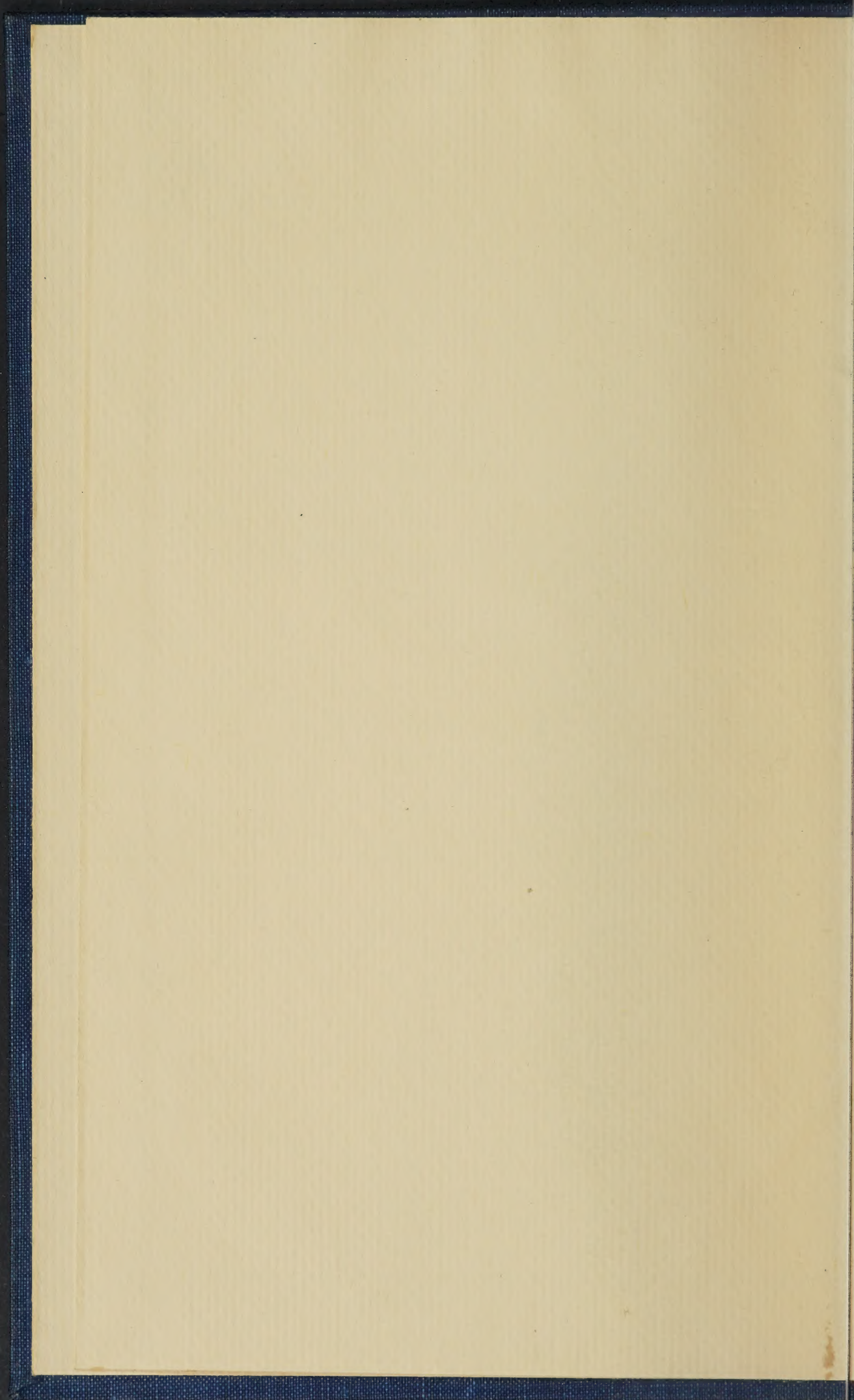


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Mr. Caldwell
1802

ARTIFICIAL FIREWORKS,

Improved to the MODERN PRACTICE,
From the MINUTEST to the HIGHEST Branches;

CONTAINING

Aigrettes	Globes	Silver-Rain
Amber-lights	Gold-Rain	Spur-Fire
Balloons	Grand Volutes	Squibs
Batteries	Leaders	Stars
Chinefe Fire-Ships	Lights	Sky-Rockets
Cohorns	Mines	Swans
Cones	Matches	Swarms
Crackers	Mortars	Thunder in Rooms
Cascades	Marrons	Towering Rockets, double and single
Dodecaedrons	Moons	Tourbillons
Ducks	Neptune's Chariot	Trees
Earthquakes	Pots	Water Fire-Works
Flights	Pumps	Wheels
Flyers	Rain-Falls	Yew-Trees, &c.
Fountains	Rockets	
Gerbes	Sea-Fights	

With all their Ingredients, Compositions, Preparations, Machines, Moulds, and Manner to make them, refining Salt-Petre, and to extract it from damaged Gun-Powder, &c.

With about 100 of the principal Figures beautifully engraved on Copper Plates.

The SECOND EDITION, corrected.

With the ADDITION of many new and beautiful Fire-Works, and three large Copper Plates.

By CAPTAIN JONES.

Also, Mr. MULLER'S FIREWORKS,
For SEA and LAND SERVICE,

His Tables for Sea and Land Cannon, which may save above 100,000*l.* a Year, by diminishing the Weight of the Guns, the Labour of Men, the Quantity of Powder in charging, from 1-half to 1-3d, 1-4th, and even to 1-5th.

P R E F A C E.

I DO not pretend to give the origin of Fire-works, which some affirm were used in the Trojan war.

It is sufficient for me, that they have flourished a long time, and continue to do so in all polite nations. I am sensible that there are many treatises on this subject, but they are imperfect and erroneous.

I have avoided prolixity without being obscure; my rules are plain, and I have endeavoured to lead the reader in the easiest manner, from the minutest circumstances to the highest, and have carefully kept to the subject. I cannot help reflecting with some chagrin, that, when we have these diversions exhibited, we have mostly had recourse to foreigners; if owing to our ignorance on this subject, I shall be happy if in my power to correct them.

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A R T I F I C I A L F I R E W O R K S.

SECT. I.—SALTPETRE.

SALTPETRE being the principal ingredient in fireworks, and a volatile body, by reason of its aqueous and ærial parts, is easily rarified by fire; but not so soon when foul and gross, as when purified from its crude and earthy parts, which greatly retard its velocity: therefore, when any quantity of Fireworks are to be made, it should be examined; for if it is not well cleansed, and of a good sort, your works will not have their proper effect; neither will it agree with the standing proportions of compositions: but to prevent accidents I shall proceed with the method of refining it.

To refine SALTPETRE.

Put into a copper, or any other vessel, 100 lb. of rough nitre with 14 gallons of clean water; let it boil gently half an hour; as it boils take off the scum; then stir it, and before it settles put it into your filtering bags, which must be hung on a rack, with glazed earthen pans under them, in which must be sticks laid across for the crystals to adhere to; it must stand in the pans 2 or 3 days to shoot, then take out the crystals and let them dry: the water that remains in the pans boil again an hour, and strain it into the pans as before, and the saltpetre will be quite clear and transparent;

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if not, it wants more refining, to do which proceed as usual, till it is well cleansed of all its earthy parts.

N. B. Those who do not chuse to procure their saltpetre by the above method, may buy it ready done, which for fireworks in general will do.

To pulverise SALTPETRE.

Take a copper kettle whose bottom must be spherical, and put into it 14 lb. of refined saltpetre, with 2 quarts or 5 pints of clean water; then put the kettle on a slow fire, and when the saltpetre is dissolved, if any impurities arise, skim them off, and keep constantly stirring it with 2 large spatulas, till all the water exhales; and when done enough, it will appear like white sand, and as fine as flour; but if it should boil too fast, take the kettle off the fire, and set it on some wet sand, which will prevent the nitre from sticking to the kettle. When you have pulverised a quantity of saltpetre, be careful to keep it in a dry place.

To extract SALTPETRE from damaged GUN-POWDER.

Have some filtering bags, hung on a rack, with glazed earthen pans under them, in the same manner as those for refining saltpetre: then take any quantity of damaged powder, and put it into a copper, with as much clean water as will cover it; when it begins to boil take off the scum, and after it has boiled a few minutes, stir it up; then take it out of the copper with a small hand kettle for that purpose, and put some into each bag, beginning at one end of the rack, so that by the time you have got to the last bag, the first will be ready for more; continue thus, till all the bags are full; then take the liquor out of the pans, which boil and filter, as before, 2 or 3 times, till the water runs quite clear, which you must let stand in the pans some time,
and

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and the saltpetre will appear at top. To get the saltpetre entirely out of the powder, take the water from that already extracted, to which add some fresh and the dregs of the powder that remain in the bags, and put them in a vessel, to stand as long as you please, and when you want to extract the nitre, you must proceed with this mixture as with the powder at first, by which means you will draw out all the saltpetre; but this process must be boiled longer than the first.

SULPHUR, or BRIMSTONE.

Sulphur is by nature the food of fire, and one of the principal ingredients in gunpowder, and almost in all compositions of fireworks; therefore great care must be taken of its being good, and brought to the highest perfection. To know when the sulphur is good, you are to observe that it is of a high yellow, and if, when held in one's hand, it crackles and bounces, it is a sign that it is fresh and good: but as the method of reducing brimstone to a powder is very troublesome, it is better to buy the flour ready made, which is done in large quantities, and in great perfection: but when a grand collection of fireworks are to be made, the strongest and best sulphur is the lump brimstone ground in the same manner as gunpowder, which you will find in the following part.

To prepare CHARCOAL for Fireworks.

Charcoal is a preservative by which the saltpetre and the brimstone is made into gun-powder, by preventing the sulphur from suffocating the strong and windy exhalation of the nitre. There are several sorts of wood made use of for this purpose; some prefer hazle, others willow and alder; but there being so little difference, you may use either, which is most convenient to be got. And the method of burning it is, Cut it in pieces about 1 or 2 feet long, then split each piece in 4 parts;

scale off the bark and hard knots, and dry them in the sun or in an oven, then make in the earth a square hole, and line it with bricks, in which lay the wood, crossing one another, and set it on fire; when thoroughly lighted and in a flame, cover the hole with boards, and fling earth over them close, to prevent the air from getting in, yet so as not to fall among the charcoal; and when it has lain thus 24 hours, take out the coals and lay them in a dry place for use. It is to be observed, that charcoal for fireworks must always be soft and well burnt, which may be bought ready done.

To make Artificial CAMPHOR.

Camphor, in the *Materia medica*, “ is a body of a particular nature, being neither a resin, a volatile salt, an oil, a juice, a bitumen, or a gum, but a mixed substance, dry, white, transparent and brittle, of a strong and penetrating smell. The Indians distinguish two kinds of it, a finer and a coarser; the finer is the produce of Borneo and Sumatra, is very rare, and is hardly ever sent into Europe; the coarser is the Japanese, which is the common, both in the Indies and in Europe.

“ The camphor, which we meet with in shops, is also of 2 kinds, differing in regard to the degree of their purity, and distinguished by the name of Rough and Refined. The tree, which produces camphor, is a species of bay tree, every part of which abounds with camphor; but is not collected from it in the manner of resins, but by a sort of chemical process. — The natives of the place where the trees grow, cut the wood and roots into small pieces, and put them into large copper vessels, which they cover with earthen heads, filled with straw; they give a moderate fire under them, and the camphor is raised in form of a white downy matter, and retained among the straw; when the process is over, they
“ shake

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“ shake it out of the straw, and knead it into cakes.
“ These cakes are not very compact, but easily crumbled to pieces; they are moderately heavy, of a greyish or dusky reddish white in colour, of a pungent smell and acrid taste, and what we call rough camphor.

“ Refined camphor must be chosen of a perfectly clean white colour, very bright and pellucid, of the same smell and taste with the rough, but more acrid and pungent.—It is so volatile that merchants usually inclose it in lin-seed, that the viscosity of that grain may keep its particles together.”

There is also an artificial camphor for fireworks, which is made from gum sandarach pulverised 2 pound, and distilled vinegar enough to cover it; put them in a glass phial, and set it 20 days in warm horfedung. Then take it out, and pour it into a large-mouth phial; and expose it to the sun a month, and you will have a concreted camphor in form of the crust of bread, and something like the natural camphor: which when you use must be ground to a powder with a little spirits of wine in a mortar. Though we have here taught the method of making artificial camphor, I would not recommend it to those who chuse to make their works to perfection, the natural camphor being by far the best.

To make the OIL of CAMPHOR,

Which is sometimes used to moisten compositions. It is produced by adding to some camphor a little oil of sweet almonds, and working them together in a brass mortar, till it turns to a green oil.

N. B. Those works that have any camphor in their compositions, should be kept as much from air as possible, or the camphor will evaporate.

BENJAMIN.

Benjamin is a resin (much used by perfumers, and sometimes in medicine); it is brought from the Indies, where it is found of different sorts; and distinguished by colours, viz. yellow, grey, and brown; but the best is that which is easy to break and full of white spots.

Benjamin is one of the ingredients in odoriferous fire-works, when reduced to a fine flour; which may be done by putting into a deep and narrow earthen pot, 3 or 4 oz. of benjamin grossly pounded; cover the pot with paper, which tie very close round the edge; then set the pot on a slow fire, and once in an hour take off the paper, and you will find some flour sticking to it, which return again in the pot; this you must continue till the flour appears white and fine. There is also an oil of benjamin, which is sometimes drawn from the dregs of the flour; it affords a very good scent, and may be used in wet compositions.

ORIGIN of GUN-POWDER.

Gun-powder being the principal ingredient in fire-works, it is proper to give a short definition of its strange explosive force, and cause of action, which, according to Dr. Shaw, the chemical cause of the explosive force of gun-powder, is, “ Each grain of powder consisting
 “ of a certain proportion of sulphur, nitre, and coal,
 “ the coal presently takes fire, upon contact of the
 “ smallest spark: at which time both the sulphur and
 “ the nitre immediately melt, and by means of the coal
 “ interposed between them, burst into flame; which
 “ spreading from grain to grain, propagates the same
 “ effect almost instantaneously: whence the whole mass
 “ of powder comes to be fired; and as nitre contains
 “ both a large proportion of air and water, which are
 “ now violently rarified by the heat, a kind of fiery
 “ explosive

FIREWORKS.

“ explosive blast is thus produced, wherein the nitre
“ seems, by its aqueous and aërial parts, to act as bel-
“ lows to the other inflammable bodies, sulphur and
“ coal, to blow them into a flame, and carry off their
“ whole substance in smoke and vapour.”

After having spoke of the nature of powder, I shall in the next place proceed to its origin, though somewhat uncertain; but it is imagined to have been invented in the time of Alexander the Great, as Philostratus speaks of a city near the river Hypafis in the Indies, that was said to be impregnable, and its inhabitants relations of the gods, because they threw thunder and lightning on their enemies; but this perhaps might be the effect of gun-powder, which, not being known to other people, might well be said to be thunder and lightning.

This conjecture has been confirmed by some travellers, who assert that it was used in the East-Indies. particularly in the Philippine Islands, about 85, which is 1265 years before it was known in Europe, where they say it was not known till 1350, though, it is said, there is mention made of gunpowder in the registers of the chambers of accounts in France, in 1338; and Friar Bacon mentions the composition of powder in express terms, in his treatise *De nullitate magiae*, published at Oxford in 1216; but we find from most accounts, that the Germans have the honour of the invention.

I should give a description of a machine for trying gun-powder, but they are so common, it would be needless; yet would have all who practise this art know, that, when they make sky rockets with powder, it must be of the best kind; but as to wheels, and other common works, any will do, only be careful it is quite dry.

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Compositions for GUN-POWDER of different kinds.

Having treated of the nature of powder, and its origin, I shall give the proportion of each ingredient, it being proper that every one who uses powder, should know of what it is composed. Therefore, I shall set down the several compositions mentioned in Casimir Siemienowicz's grand art of artillery, in which there are six sorts, viz.

I.	} Saltpetre 100 lb. fulphur	{ 25 lb.	} and coal	{ 25 lb.
II.				
III.				
IV.				
V.				
VI.				
		{ 18 lb.		{ 20 lb.
		{ 12 lb.		{ 15 lb.
		{ 20 lb.		{ 24 lb.
		{ 15 lb.		{ 18 lb.
		{ 10 lb.		{ 8 lb.

Belidor, in his Hydraulics, speaks of a composition for gun-powder, which is, to 30 lb. of saltpetre, add 5 lb. of fulphur, with as much coal: but the proportions of the several ingredients are to be found best by experience. Though there has been so much practice in making powder, there has not yet been ascertained a standing proportion of the nitre, fulphur, and coal; but it is hoped that in time this great and noble invention will be much improved, and that the different and best quantity of every ingredient will be ascertained. At the powder mills they generally allow for wasting, in making up, $1 \frac{1}{2}$ lb. in 100. Their mixture for 100 of good powder is thus: To $76 \frac{1}{2}$ lb. of saltpetre, well refined and dry'd, $12 \frac{1}{2}$ lb. of coal, and as much fulphur, which makes $101 \frac{1}{2}$ lb. which when worked up will nearly weigh 100. As gun-powder is capable of being improved, I shall not omit any particular that may be of service to such as are willing to make experiments; viz. refined saltpetre 5 lb. fulphur 1 lb. 4 oz. and charcoal $7 \frac{1}{2}$ oz.

Though

Though you may have a good proportion of ingredients, the powder will not always be the same: much depends on their being well incorporated, corned and dry'd, the method of which will be taught in the next article.

To restore damaged GUN-POWDER to its proper strength.

It is certain, that, if powder is kept long in a damp place, it will become weak, and great part formed into hard lumps, a sure sign of its being damaged. When powder is thus found, you will see at the bottom of the barrel some saltpetre, which, by being wet, will separate from the sulphur and coal, and fall to the bottom of the vessel, and settle in the form of a white downey matter; but the only method to prevent this, is to move the barrels as oft as convenient, and place them on their opposite sides or ends: but though the greatest care be taken, length of time will greatly lessen its primitive strength.

Therefore when any of these accidents happens, you may recover it by applying to these directions; for example, if you imagine that it has not received much damage, proceed thus. Spread it on canvas, or dry boards, and expose it to the sun, then add to it an equal quantity of good powder, and mix them well, and, when thoroughly dry, barrel, and put it in a dry and proper place. But if gun-powder is quite bad, the method to restore it is; first, you must know what it weighed when good; then, by weighing it again, you find how much it has lost by the separation and evaporation of the saltpetre; then add to it as much refined saltpetre, as it has wasted, but as a large quantity of this would be difficult to mix, it will be best to put a proportion of nitre to every 20lb. of powder; when done, put one of these proportions into your mealing table, and grind it, till you have brought it to an impalpable powder, then scarce it with a fine sieve; but if
any

To

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any remain in the sieve that will not pass, return it to the table, and grind it again, till you have made it all fine enough to go through; being thus well ground and sifted, it must be made into grains thus: first you must have some (copper wire sieves) made to what size you intend the grains should be; these are called corning sieves or grainers, which fill with the powder composition, then shake them about, and the powder will pass through the sieve, formed into grains. Having thus corned it, set it to dry in the sun; and when quite dry, searce it with a fine hair sieve, to separate the dust from the grains. This dust may be worked with another mixture; so that none will be wasted: but sometimes it may happen, that the weight when good cannot be known; in which case add to each lb. 1 oz. or $1 \frac{1}{2}$ oz. of saltpetre, according as the powder is decayed, and then grind, sift, and granulate it as before.

N. B. If you have a large quantity of powder, that is very bad, and quite spoiled; the only way is to extract the saltpetre from it, according to the usual manner: for powder thus circumstanced, will be very difficult to recover.

SILENT POWDER, commonly called WHITE POWDER.

It would be rather absurd to imagine, that it is possible for gun-powder to have any effect without some report, when it is well known, that the sound does not proceed from the powder only, but from the air being rarified by the expansion of it.

It is evident, that any composition acting with the same explosive force, will produce the same effect, in every respect. Yet for such I never had any proof, nor ever knew any experiment made of it, but have so little faith in it, that I should not have given it a place in this work, had it not been treated of by some authors of note; and at the same time giving every one, who
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is fond of this art, all opportunities of making experiments, and of knowing every thing relating to it.

To make SILENT POWDER.

For the first sort, mix 2 lb. of borax, with 4 lb. of gun-powder,

2d. Add $\frac{1}{2}$ lb. of lapis-calaminaris, and $\frac{1}{2}$ lb. of borax, to 2 lb. of powder.

3d. To 6 lb. of gun-powder $\frac{1}{2}$ lb. of calcined moles, with as much borax of Venice.

4th. To 6 $\frac{1}{2}$ lb. of saltpetre, 8 $\frac{1}{2}$ lb. of sulphur, and $\frac{1}{2}$ lb. of the second bark of an elder tree, burnt and ground to a powder, with 2 lb. of common salt.

There are many other methods of making silent powder, according to report, by using camphor or touch-wood instead of charcoal, or by adding to the common powder burnt paper, hay seed, &c. When any of these ingredients are to be mixed with common powder, grind them together, and make them into grains.

GUN-POWDER of different Colours.

Notwithstanding the repeated trials and experiments, made by the greatest artists, to add to the strength of gun-powder, all have proved ineffectual, and most have agreed that the present powder will not admit of a fourth ingredient: therefore it is evident, that any thing being mixed with the present composition would rather reduce its strength than add to it; consequently coloured powder must be weaker than black: so that the making of powder of different colours, is only a fancy that serves to please the curious, without any other effect.

To make GUN-POWDER white.

To 6 lb. of salt-petre, add 1 lb. of the pith of an elder tree, well dried and pulverised, with a sufficient quantity

tity of brimstone to make it into powder, which you will find in the composition of gun-powder, or 1 oz. of the salt of tartar, calcined till it comes white, and then boiled in clear water, till the water is all evaporated.

To make POWDER red.

Boil in water some brasil wood or vermillion and 1 lb. of chopped paper; and, when boiled for some time to draw out the colour, dry and meal it with 1 lb. of sulphur, and 8 lb of saltpetre.

Or, to 6 lb. of saltpetre, 1 lb. of sulphur, and $\frac{1}{2}$ lb. of amber, and blood stone 1 lb.

To make Yellow POWDER.

Take 8 lb. of saltpetre, 1 lb. of sulphur, and 1 lb. of wild saffron, that has been boiled in aqua vitæ, and afterwards made dry and mealed.

To make Green POWDER.

Boil 2 lb. of rotten wood, with some verdegrease in aqua vitæ, then dry and pound it, and mix it with 1 lb. of sulphur, and 10 lb. of saltpetre.

To make Blue POWDER.

Boil some indigo in aqua vitæ, with 1 lb. of the bark of a young linden tree, then dry and reduce it to a powder, and mix it with 1 lb. of brimstone, and 8 lb. of saltpetre.

To make Pulvis Fulminans, or Thunder in a Room.

This composition is simple, yet has a very curious effect; it is made 3 parts of saltpetre, 2 of salt of tartar, and 1 of sulphur, all ground to a fine powder, and well mixt. As the effect of this powder is quite different from
that

that of gun-powder, so is there a different method of firing it, which is thus: Put about 2 tea spoonfulls of it into a fire-shovel, or iron ladle, and set it over a slow fire, and when it is quite hot, it will go off with a violent report. There is something surprising in the nature of this composition; for as the common powder acts every way equal, and makes the greatest noise when confined, this, on the contrary, acts only downwards, and makes the strongest report when not confined.

There is another sort of fulminating powder, called fulminans aurum, on account of there being gold mixed in its composition, which is done by a chemical preparation; but as the preparing of the ingredients requires a tedious and expensive process, I shall omit the method of doing it, and let those who chuse to make chemical experiments refer to authors on that subject, by whom they will find the manner of making it. It is said one grain of fulminans aurum, when made to perfection, and held on the point of a knife, over a candle, will make a report louder than a musket.

SECT. II.—SPUR-FIRE.

THIS fire is the most beautiful and curious of any yet known, and was invented by the Chinese, but now is in greater perfection in England than in China. As it requires great trouble to make it to perfection, it will be necessary that beginners should have full instructions; therefore care should be taken that all the ingredients are of the best, that the lamp-black is not damp and clodded, that the saltpetre and brimstone are thoroughly refined. This composition is generally rammed in 1 or 2 ounce cases, about 5 or 6 inches long, but not drove very hard; and the cases must have their concave stroke struck very smooth, and the choak or vent not quite so large as the usual proportion; this charge, when driven and kept a few months, will be much better than
when

when rammed, but will not spoil, if kept dry, in many years.

As the beauty of this composition cannot be seen at so great a distance as brilliant fire, it has a better effect in a room than in the open air, and may be fired in a chamber without any danger: it is of so innocent a nature, that, though with an improper phrase, it may be called a cold fire; and so extraordinary is the fire produced from this composition, that, if well made, the sparks will not burn a handkerchief, when held in the midst of them; you may hold them in your hand while burning, with as much safety as a candle; and if you put your hand within a foot of the mouth of the case, you will feel the sparks like drops of rain. When any of these spur-fires are fired singly, they are called artificial flower pots; but some of them placed round a transparent pyramid of paper, and fired in a large room, make a very pretty appearance.

Composition for the SPUR-FIRE.

Saltpetre 4lb. 8 oz. sulphur 2lb. and lamp-black 1 lb. 8 oz.

Or, saltpetre 1 lb. sulphur $\frac{1}{2}$ lb. and lamp-black 4 quarts.

The spur-fire composition being very difficult to mix, and the manner of doing it quite different from any other, I shall here treat of it separately; for example, the saltpetre and the brimstone must be first sifted together, and then put into a marble mortar, and the lamp-black with them, which you work down by degrees, with a wooden pestle, till all the ingredients appear of one colour, which will be something greyish, but very near black; then drive a little into a case for trial, and fire it in a dark place; and if the sparks, which are called stars, or pinks, come out in clusters, and afterwards spread well without any other sparks, it is a sign of its being good, otherwise not; for if any drossy sparks appear, and the stars not full, it is then not mixed enough; but if the pinks are very

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very small, and soon break, it is a sign that you have rubbed it too much.

N.B. This mixture, when rubbed too much, will be too fierce, and hardly shew any stars; and, on the contrary, when not mixed enough, will be too weak, and throw out an obscure smoke, and lumps of dross, without any stars. The reason of this charge being called the spur-fire, is because the sparks it yields have a great resemblance to the rowel of a spur, from whence it takes its name.

Characters to the Ingredients used in Fireworks.

Meal	}	Powder	_____	_____	_____	M
Corned			_____	_____	_____	2
Saltpetre			_____	_____	_____	9
Brimstone			_____	_____	_____	Z
Crude Sulphur			_____	_____	_____	CZ
Charcoal			_____	_____	_____	C +
Sea Coal			_____	_____	_____	CS
Saw-duft or Beech-raspings			_____	_____	_____	BR
Steel or Iron filings			_____	_____	_____	S X
Brass	}	duft	_____	_____	_____	B X
Glass			_____	_____	_____	G X
Tanners			_____	_____	_____	T X
		of Bark	_____	_____	_____	
Cast Iron			_____	_____	_____	CI
Antimony Crude			_____	_____	_____	CA
Camphor			_____	_____	_____	x
Yellow Amber			_____	_____	_____	AY
Lapis Calaminaris			_____	_____	_____	LS
Gum			_____	_____	_____	6
Lamp Black			_____	_____	_____	BL
Ising Glass			_____	_____	_____	GI
Spirit	}	of	_____	_____	_____	W
Spirits			_____	_____	_____	ST
Oil of Spike			_____	_____	_____	PO
		Wine	_____	_____	_____	
		Turpentine	_____	_____	_____	

Their

Their use is, that by them the receipts may be contracted, so that they may be contained in a leaf of a pocket book, which is much less than any table that has yet been invented. And they are convenient for travellers.

To meal GUN-POWDER, BRIMSTONE, and CHARCOAL.

There have been many methods used to grind these ingredients to a powder for fireworks, such as large mortars and pestles, made of ebony, and other hard wood; and horizontal mills with brass barrels; but none have proved so effectual and speedy as the last invention, that of the mealing table, represented in Plate I. Fig. 1. made of elm, with a rim round its edge, 4 or 5 inches high; and at the narrow end, A, is a slider, that runs in a groove and forms part of the rim; so that when you have taken out of the table, as much powder as you can, with the copper shovel Fig. 2. sweep all clean out at the slider A. When you are going to meal a quantity of powder, observe not to put too much in the table at once; but when you have put in a good proportion, take the muller, Fig. 3. and rub it till all the grains are broke; then searce it, in a lawn sieve that has a receiver and top to it; and that which does not pass through the sieve, return again to the table and grind it, till you have brought it all fine enough to go through the sieve. Brimstone and charcoal are ground in the same manner, only the muller must be made of ebony; for these ingredients, being harder than powder, would stick in the grain of elm, and be difficult to grind; as brimstone is apt to stick and clod to the table, it will be best to keep one for that purpose, by which means you will always have your brimstone clean and well ground.

To prepare CAST-IRON for Gerbes, White Fountains, and Chinese Fire.

Cast-iron being of so hard a nature, as not to be cut by a file, we are obliged to reduce it into grains, though somewhat difficult to perform; but if we consider what beautiful sparks this sort of iron yields, no pains should be spared to granulate such an essential material, to do which, get at an iron foundry some thin pieces of iron, such as generally runs over the moulds at the time of casting: then have a square block made of cast iron, and an iron square hammer about 4 lb. weight; then, having covered the floor with cloth, or something to catch the beatings, lay the thin pieces of iron on the block, and beat them with the hammer, till reduced into small grains, which afterwards scarce with a very fine sieve, to separate the fine dust, which is sometimes used in small cases of brilliant fire, instead of steel dust; and when you have got out all the dust, sift what remains with a sieve a little larger, and so on with sieves of different sizes, till the iron passes through about the bigness of small bird shot: your iron thus beat and sifted, put each sort into wooden boxes or oiled paper, to keep it from rusting. When you use it, observe the difference of its size, in proportion to the cases for which the charge is intended; for the coarse sort is only designed for very large gerbes, of 6 or 8 lb.

Charges for Sky-Rockets, &c.

Rockets of Four Ounces.

Mealed powder 1 lb. 4 oz. saltpetre 4 oz. and charcoal 2 oz.

Rockets of Eight Ounces.

I. Mealed powder 1 lb. saltpetre 4 oz. brimstone 3 oz. and charcoal 1 oz. and $\frac{1}{2}$.

II. Meal powder 1 lb. and $\frac{1}{2}$, and charcoal 4 oz. and $\frac{1}{4}$.

Rockets of One Pound.

Meal powder 2 lb. saltpetre 8 oz. brimstone 4 oz. charcoal 2 oz. and steel filings 1 oz. and $\frac{1}{2}$.

Sky Rockets in general.

I. Saltpetre 4 lb. brimstone 1 lb. and charcoal 1 lb. $\frac{1}{2}$.

II. Saltpetre 4 lb. brimstone 1 lb. $\frac{1}{2}$. charcoal 1 lb. 12 oz. and meal powder 2 oz.

Large Sky Rockets.

Saltpetre 4 lb. meal powder 1 lb. and brimstone 1 lb.

Compositions to be used in Rockets of a middling size.

I. Saltpetre 8 lb. sulphur 3 lb. meal powder 3 lb.

II. Saltpetre 3 lb. sulphur 2 lb. meal powder 1 lb. charcoal 1 lb.

Compositions for Rocket Stars.

White Stars.

Meal powder 4 oz. saltpetre 12 oz. sulphur vivum 6 oz. oil of spike 2 oz. and camphor 5 oz.

Blue Stars.

Meal powder 8 oz. saltpetre 4, sulphur 2, spirits of wine 2, and oil of spike 2.

Coloured

Coloured, or variegated Stars.

Meal powder 8 drams, rochpetre 4 oz. sulphur vivum 2, and camphor 2.

Brilliant Stars.

Saltpetre $3\frac{1}{2}$ oz. sulphur $1\frac{1}{2}$, and meal powder $\frac{3}{4}$, worked up with spirits of wine only.

Common Stars.

Saltpetre 1 lb. brimstone 4 oz. antimony $4\frac{3}{4}$, isinglass $\frac{1}{2}$, camphor $\frac{1}{2}$, and spirits of wine $\frac{3}{4}$.

Tailed Stars.

Meal powder 3 oz. brimstone 2, saltpetre 1, and charcoal (coarsely ground) $\frac{1}{4}$.

Drove Stars.

I. Saltpetre 3 lb. sulphur 1 lb. brass dust 12 oz. antimony 3.

II. Saltpetre 1 lb. antimony 4 oz. and sulphur 8.

Fixed Pointed Stars.

Saltpetre $8\frac{1}{2}$ oz. sulphur 2, antimony 1 oz. 10 dr.

Stars of a Fine Colour.

Sulphur 1 oz. meal powder 1, saltpetre 1, camphor 4 dr. oil of turpentine 4 dr.

Gold Rain for Sky Rockets.

I. Saltpetre 1 lb. meal powder 4 oz. sulphur 4, brass dust 1, saw dust $2\frac{1}{4}$, and glass dust 6 dr.

II. Meal powder 12 oz. saltpetre 2, charcoal 4.

C 2

III.

III. Saltpetre 8 oz. brimstone 2, glass dust 1, antimony $\frac{3}{4}$, brass dust $\frac{1}{4}$, and saw dust 12 dr.

Silver Rain.

I. Saltpetre 4 oz. sulphur, meal powder, and antimony of each 2 oz. sal prunella $\frac{1}{2}$ oz.

II. Saltpetre $\frac{1}{2}$ lb. brimstone 2 oz. and charcoal 4.

III. Saltpetre 1 lb. brimstone $\frac{1}{4}$ lb. antimony 6 oz.

IV. Saltpetre 4 oz. brimstone 1, powder 2, and steel dust $\frac{3}{4}$ oz.

Water Rockets.

I. Meal powder 6 lb. saltpetre 4, brimstone 3, charcoal 5.

II. Saltpetre 1 lb. brimstone $4\frac{1}{2}$ oz. charcoal 6.

III. Saltpetre 1 lb. brimstone 4 oz. charcoal 12 oz.

IV. Saltpetre 4 lb. brimstone 1 lb. 8 oz. charcoal 1 lb. 12 oz.

V. Brimstone 2 lb. saltpetre 4 lb. and meal powder 4.

VI. Saltpetre 1 lb. meal powder 4 oz. brimstone $8\frac{1}{2}$, charcoal 2.

VII. Meal powder 1 lb. saltpetre 3, brimstone 1. sea-coal 1 oz. charcoal $8\frac{1}{2}$, saw dust $\frac{3}{4}$, steel dust $\frac{1}{2}$, and coarse charcoal $\frac{1}{4}$ oz.

VIII. Meal powder $1\frac{3}{4}$ lb. saltpetre 3, sulphur $1\frac{1}{2}$, charcoal 12 oz. saw dust 2.

Sinking Charge for Water Rockets.

Meal powder 8 oz. charcoal $\frac{3}{4}$ oz.

Wheel Cases from 2 oz. to 4 lb.

I. Meal powder 2 lb. saltpetre 4 oz. iron filings 7.

II. Meal powder 2 lb. saltpetre 12 oz. sulphur 4, steel dust 3.

III. Meal powder 4 lb. saltpetre 1 lb. brimstone 8 oz. charcoal $4\frac{1}{2}$.

IV.

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IV. Meal powder 8 oz. saltpetre 4, saw dust $1\frac{1}{2}$, sea-coal $\frac{3}{4}$.

V. Meal powder 1lb. 4 oz. brimstone 4 oz. 10 dr. saltpetre 8 oz. glass dust $2\frac{1}{2}$.

VI. Meal powder 12 oz. charcoal 1, saw dust $\frac{1}{2}$.

VII. Saltpetre 1lb. 9 oz. brimstone 4 oz. charcoal $4\frac{1}{2}$.

VIII. Meal powder 2lb. saltpetre 1, brimstone $\frac{1}{2}$, and sea-coal 2 oz.

IX. Saltpetre 2lb. brimstone 1, meal powder 4, and glass dust 4 oz.

X. Meal powder 1lb. saltpetre 2 oz. and steel dust $3\frac{1}{2}$.

XI. Meal powder 2lb. and steel dust $2\frac{1}{2}$ oz. with $2\frac{1}{2}$ of the fine dust of beat iron.

XII. Saltpetre 2lb. 13 oz. brimstone 8 oz. and charcoal 6.

Slow Fire for Wheels.

I. Saltpetre 4 oz. brimstone 2, and meal powder $1\frac{1}{2}$.

II. Saltpetre 4 oz. brimstone 1, and antimony 1 oz. 6 dr.

III. Saltpetre $4\frac{1}{2}$ oz. brimstone 1 oz. and mealed powder $1\frac{1}{2}$.

Dead Fire for Wheels.

I. Saltpetre $1\frac{1}{4}$ oz. brimstone $\frac{1}{4}$, lapis-calaminaris $\frac{1}{4}$, and antimony 2 dr.

Standing or fixed Cases.

I. Meal powder 4lb. saltpetre 2, brimstone and charcoal 1.

II. Meal powder 2lb. saltpetre 1, and steel dust 8 oz.

III. Meal powder 1lb. 4 oz. and charcoal 4 oz.

IV. Meal powder 1lb. and steel dust 4 oz.

V. Meal powder $2\frac{1}{2}$ lb. brimstone 4 oz. and sea coal 6.

VI. Meal powder 3 lb. charcoal 5 oz. and saw dust $1\frac{1}{2}$.

Sun Cafes.

I. Meal powder $8\frac{1}{2}$ lb. saltpetre 1 lb. 2 oz. steel dust 2 lb. $10\frac{1}{2}$ oz. brimstone 4.

II. Meal powder 3 lb. saltpetre 6 oz. and steel dust $7\frac{1}{2}$.

A Brilliant Fire.

Meal powder 12 lb. saltpetre 1, brimstone 4 oz. steel dust $1\frac{1}{2}$ lb.

Gerbes.

Meal powder 6 lb. and beat iron 2 lb. $1\frac{1}{2}$ oz.

Chinefe Fire.

Saltpetre 12 oz. meal powder 2 lb. brimstone 1 lb. 2 oz. and beat iron 12 oz.

Charge for Four-ounce Tourbillons.

Meal powder 2 lb. 4 oz. and charcoal $4\frac{1}{2}$ oz.

Eight-ounce Tourbillons.

Meal powder 2 lb. and charcoal $4\frac{3}{4}$ oz.

Large Tourbillons.

Meal powder 2 lb. saltpetre 1, brimstone 8 oz. and beat iron 8.

N. B. Tourbillons may be made very large, and of different colour'd fires; only you are to observe, that the larger they are, the weaker must be the charge; and, on the contrary, the smaller, the stronger their charge.

Water Ballóons.

I. Saltpetre 4 lb. brimstone 2, meal powder 2, antimony 4 oz. saw dust 4, and glass dust $1\frac{1}{4}$.

II.

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II. Saltpetre 9 lb. brimstone 3 lb. meal powder 6 lb.
rosin 12 oz. and antimony 8 oz.

Water Squibs.

I. Meal powder 1 lb. and charcoal 1 lb.

II. Meal powder 1 lb. and charcoal 9 oz.

Mine Ports or Serpents.

I. Meal powder 1 lb. and charcoal 1 oz.

II. Meal powder 9 oz. charcoal 1 oz.

Port-fires for firing Rockets, &c.

I. Saltpetre 12 oz. brimstone 4 oz. and meal powder 2 oz.

II. Saltpetre 8 oz. brimstone 4 oz. and meal powder 2 oz.

III. Saltpetre 1 lb. 2 oz. meal powder 1 $\frac{1}{2}$ lb. and brimstone 10 oz. This composition must be moistened with one gill of linseed oil.

IV. Meal powder 6 oz. saltpetre 2 lb. 2 oz. and brimstone 10 oz.

V. Saltpetre 1 lb. 4 oz. meal powder 4 oz. brimstone 5 oz. saw dust 8 oz.

VI. Saltpetre 8 oz. brimstone 2 oz. and meal powder 2 oz.

Port-fires for Illuminations.

Saltpetre 1 lb. brimstone 8 oz. and meal powder 6 oz.

Cones or Spiral Wheels.

Saltpetre 1 $\frac{1}{2}$ lb. brimstone 6 oz. meal powder 14 oz. and glass dust 14 oz.

Crowns or Globes.

Saltpetre 6 oz. brimstone 2 lb. antimony 4 oz. and camphor 2 oz.

Air

Air Ballóon Fuzes.

I. Saltpetre 1 lb. 10 oz. brimstone 8 oz. and meal powder 1 lb. 6 oz.

II. Saltpetre 1 $\frac{1}{2}$ lb. brimstone 8 oz. and meal powder 1 lb. 8 oz.

Serpents for Pots des Brins.

Meal powder 1 lb. 8 oz. saltpetre 12 oz. and charcoal 2 oz.

Fire Pumps.

I. Saltpetre 5 lb. brimstone 1 lb. meal powder 1 $\frac{1}{2}$ lb. and glass dust 1 lb.

II. Saltpetre 4 lb. 8 oz. brimstone 2 lb. meal powder 1 lb. 8 oz. and glass dust 1 lb. 8 oz.

A Slow White Flame.

I. Saltpetre 2 lb. sulphur 3 lb. antimony 1 lb.

II. Saltpetre 3 $\frac{1}{2}$ lb. sulphur 2 $\frac{1}{2}$ lb. meal powder 1 lb. antimony $\frac{1}{2}$ lb. glass dust 4 oz. brass dust 1 oz.

N. B. These compositions, driven 1 $\frac{1}{4}$ inch in a 1 oz. case, will burn 1 minute, which is much longer time than an equal quantity of any composition, yet known, will last.

Amber Lights.

Meal powder 9 oz. amber 3 oz. This charge may be drove in small cases, for illuminations.

Lights of another Kind.

Saltpetre 3 lb. brimstone 1 lb. meal powder 1 lb. antimony 10 $\frac{1}{2}$ oz. All these must be mixed with the oil of spike,

A Red Fire.

Meal powder 3 lb. charcoal 12 oz. and saw dust
8 oz.

A Common Fire.

Saltpetre 3 lb. charcoal 10 oz. and brimstone 2 oz.

To make an Artificial Earthquake.

Mix the following ingredients to a paste with water, and then bury it in the ground, and in a few hours the earth will break and open in several places. The composition: Sulphur 4 lb. and steel dust 4 lb.

Having laid down, under the preceding heads, the different compositions used in fireworks by our modern artists; I shall, in the next place, give some tables of charges that were formerly used, according to the several accounts given by those authors from whom they are collected: but if the reader will consider, he will find the charges in these tables to be very uncertain, by comparing their method of determining the size and weight of rockets, and the proportions of ingredients thereto, with the method taught in this work, which is so plain, easy, and certain, that I never yet knew it fail; and doubt not, but that it will be so allowed by all who chuse to make the trial.

The subsequent table is taken from Siemienowicz, wherein are specified the different charges of sky rockets, from $\frac{1}{2}$ oz. to 100 lb.; the charges being calculated in proportion to the weight of a leaden ball of the same diameter as the bore of each mould; which bores are divided into inches and lines,* and each line into 12 = parts, according to the French method.

* A line is the 12th part of an inch.

T A B. I.

Charges for Rockets, &c.

Ball's weight.	Mould's diam.	Pow- der.	Salt- petre.	Brim- stone.	Char- coal.
lb. oz.	in. l. ts.	b. oz.	lb. oz.	lb. oz.	lb. oz.
$\frac{1}{2}$	0 6 3				
1	0 7 8	0 15	0 0	0 0	0 2
2	0 9 7	0 12	0 2	0 $\frac{1}{2}$	0 $1\frac{1}{2}$
3	0 11 0				
4	1 0 1				
5	1 1 0	1 3	0 12	0 4	0 $1\frac{1}{2}$
6	1 1 10				
7	1 2 7				
8	1 3 4				
9	1 3 11				
10	1 4 5				
11	1 5 0				
12	1 5 5				
13	1 6 0				
14	1 6 5				
16	1 7 3	18 0	8 0	2 0	4 0
2 0	2 0 3	0 0	60 0	2 0	15 0
3 0	2 3 7				
4 0	2 6 9				
5 0	2 8 8	0 0	64 0	8 0	16 0
6 0	2 10 9				
8 0	3 2 6				
10 0	3 5 4	0 0	62 0	9 0	20 0
12 0	3 7 10				
15 0	3 11 4				
17 0	4 1 5	0 0	64 0	12 0	16 0
20 0	4 4 2				
27 0	4 9 9				
30 0	4 11 6	0 0	30 0	7 0	18 0
40 0	5 5 1				
60 0	6 3 3				
100 0	7 5 3	0 0	30 0	10 0	20 0

T A B.

T A B. II.

Rocket, &c. Charges.

From a late French author*, who regulated his charges according to the interior diameter of the mould, divided into lines.

Interior diameter of the mould.	Rocket's Weight.	Saltpe-tre.	Brim-stone.	Char-coal.
Lines.	lb. oz. dr.	ounces.	ounces.	ounces.
6	0 0 4			
7	0 0 6	44	4	16
8	0 1 1			
9	0 1 5			
10	0 2 2	40	4	16
11	0 3 0			
12	0 3 7			
13	0 4 6	38	4	16
14	0 6 1			
15	0 7 4			
16	0 9 1	36	4	16
17	0 11 0			
18	0 13 1			
19	0 15 4	34	4	16
19 $\frac{1}{4}$	1 0 0			
21	1 7 1			
24	1 15 1	32	5	16
30	4 0 0			
36	6 9 0	30	6	18
72	55 8 0			

* Traité des feux d'artifice, par M. F***.

T A B. III.

S K Y - R O C K E T S.

The charges adapted to the weight of composition in each, after Hanzelet's method.

Composition Wt.	Powder	Saltpetre.	Brimstone.	Charcoal.
lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.
0 1 $\frac{1}{2}$	0 4			0 1
or,	1 0	0 1 $\frac{1}{2}$		0 1 $\frac{1}{2}$
0 2	0 4	0 1		
or,	0 4			0 1 $\frac{1}{2}$
0 4	1 0	0 4		0 4
0 8		0 4		
	0 3	0 10	0 1	0 3
	0 10	0 3 $\frac{1}{2}$	0 1	0 3 $\frac{1}{2}$
1 0	1 0		0 1	0 2
or,		1 4	0 2	0 3 $\frac{1}{2}$
3 0		1 14	7 7 $\frac{1}{2}$	0 11
6 0		3 1 0	4 8	10 0
7 0		8 0	1 8	2 12
8 0				
10 0				

T A B. IV.

From Henrion, whose method is as in the preceding.

Composition Wt.	Powder	Saltpe- tre.	Brim- stone.	Char- coal.
lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.
1	1 0			0 2
2	1 0	1 0		0 1
or, 3	4 $\frac{1}{2}$	0 1		0 1
4	4 0	1 0	0 $\frac{1}{2}$	0 4
8	1 8	0 4		0 2
or, 1	1 0	0 4		0 1
8	3 $\frac{1}{2}$	0 10		0 $3\frac{1}{2}$
10	2 5	0 0	0 2 steel dust	0 6
12	17 0	0 4	0 2 0 $3\frac{1}{2}$	0 7
14	2 8	0 9	0 3 steel dust	0 3
15	1 0	0 0	0 3 0 1	0 3
1 0	0 2	0 12	0 1	0 3
2 0	0 0	8 0	1 4 steel dust	2 2
3 0			0 2	
10 0				

T A B. V.

Charges for Sky-Rockets,

From M. de Saint Remy, improved by M. F***.

Composition for a Rocket of

2 lb. | 1 lb. | $\frac{1}{2}$ lb. | 4 oz. | $1\frac{1}{2}$ oz.

CORRECTED

By M. F***, 1 lb.	11 oz.	$7\frac{1}{2}$ oz.	6 oz. 5 dr.	1 oz. 5 dr.
lb. oz.	lb. oz.	lb. oz.	oz.	oz.
Pow. 2 0	1 0	1 4	5	8 or 9
Saltp. 1 0	12	12	1	$\frac{1}{5}$
Brimst. 5	2	1	$\frac{1}{4}$	
Charc. 4		3	$\frac{1}{2}$	$\frac{1}{2}$ or 1
Steel-d. 2		2		

Mould Height, in Inches.

 $9\frac{1}{2}$ in. | $8\frac{1}{2}$ | $7\frac{1}{2}$ | 7 | $4\frac{1}{2}$

Diameter, in Inches and Lines.

1 in. 7 l. | 1 5 | 1 3 | 1 2 | 9 lines

French Names for Sky Rockets.

Double Mar- quise.	Marquise.	Grosse de- partement	Departement.	Fusée de Caiffe
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Remarks

Remarks on the foregoing Tables.

In the first, we find that the compositions for all rockets under 1lb. are made chiefly of gunpowder and charcoal, which method has been long proved erroneous in many respects: first, that rockets made with such charges will not keep long without spoiling; secondly, that they are very uncertain in performing their proper effect; thirdly, they will carry but a short tail, with a black and smoaky fire.

We also find those charges for rockets above 1lb. that are composed of saltpetre, brimstone, and charcoal, to be too strong; by which we should imagine that, at the time when they were used, the piercers did not bear the same proportion to the rockets, as those used by our present artists; as it is on the size of the cavity in the composition, that the effect of the rocket and proportion of the charge depends: which I shall endeavour to shew hereafter.

Table II. is given, by the author, as an improvement on the first; wherein he takes notice of the charges being too many in number; he has therefore reduced them to 7, which, according to his opinion, are sufficient for rockets of any size: he also observes, that the ingredients are expressed in unequal quantities; which he has likewise laid down in a more regular order. By the same author's account, rockets were made in France, not many years since, with the compositions mentioned in his table. I shall not here pretend to say, that rockets were not made with the charges given in the said table; yet can affirm, by experience, that several of them will not agree with our present moulds.

As to the method prescribed in tables III. and IV. it is difficult to determine whether we shall praise or condemn them, as they were wrote when the art of making fireworks was in its infancy; as may be seen by their strange method of determining the proportion of ingredients,

dients, and weight of rockets, by the quantity of composition contained in each case; which must have required a very nice calculation; for at that time they had not fixed upon an exact length for rockets, but made them from 6 to 9 diameters long: all which differ so much from our modern practice, that I never thought it worth the trouble of making a trial; but am of opinion, that very few of the charges will answer.

In the fifth Table, the compositions are in proportion to the weight of the rocket, with its head and stick, all complete; which head and stick are equal to the weight of the rocket, according to the improvement made by M. F***, as in the second column from the top: he has also added the diameters to the moulds, in proportion to their height, allowing each 6 diameters, which supposing to be right, the rockets will be nearly reduced to $\frac{1}{2}$ their weight given in the first column. On the charges in this table I have made no experiment, therefore cannot recommend them as proof.

Having given a variety of charges for sky-rockets, in the preceding tables, which are collected from the principal authors on this subject, together with remarks, I shall, in the next place, according to my promise of not omitting any thing that may be of service to the reader, add some compositions for rocket-stars of several colours, as inserted by former authors.

Compositions for Stars of different Colours:

I. Meal powder 4 oz. saltpetre 2 oz. brimstone 2 oz. steel dust 1 $\frac{1}{2}$ oz. and camphor, white amber, antimony, and mercury-sublimate, of each $\frac{1}{2}$ oz.

II. Rochepetre 10 oz. brimstone, charcoal, antimony, meal powder, and camphor, of each $\frac{3}{4}$ oz. moistened with oil of turpentine. These compositions are made into stars, by being worked to a paste with aqua vitæ, in which has been dissolved some gum-tragacanth; and after you have rolled them in powder, make a hole through the middle of each, and string them on quick-match, leaving about 2 inches between each.

III. Saltpetre 8 oz. brimstone 2 oz. yellow amber 1 oz. antimony 1 oz. and powder 3 oz.

IV. Brimstone 2 $\frac{1}{2}$ oz. saltpetre 6 oz. olibanum or frankincense in drops 4 oz.; mastick, and mercury-sublimate, of each 4 oz. meal powder 5 oz. white amber, yellow amber, and camphor, of each 1 oz. antimony and orpiment $\frac{1}{2}$ oz. each.

V. Saltpetre 1 lb. brimstone $\frac{1}{2}$ lb. and meal powder 8 oz. moistened with pottolio-oil.

VI. Powder $\frac{1}{2}$ lb. brimstone and saltpetre, of each 4 oz.

VII. Saltpetre 4 oz. brimstone 2 oz. and meal powder 1 oz.

Stars that carry Tails of Sparks.

I. Brimstone 6 oz. antimony crude 2 oz. saltpetre 4 oz. and rosin 4 oz.

II. Saltpetre, rosin, and charcoal, of each 2 oz. brimstone 1 oz. and pitch 1 oz.

These compositions are sometimes melted in an earthen pan, and mixed with chopped cotton-match, before they are rolled into stars, but will do as well if wetted, and worked up in the usual manner.

Stars that yield some Sparks.

I. Camphor 2 oz. saltpetre 1 oz. meal powder 1 oz.

II. Saltpetre 1 oz. ditto melted $\frac{1}{2}$ oz. and camphor 2 oz. When you would make stars of either of these compositions, you must wet them with gum water, or spirit of wine, in which has been dissolved some gum-arabick, or gum-tragacanth, that the whole may have the consistence of a pretty thick liquid; having thus done, take 1 oz. of lint, and stir it about in the composition till it becomes dry enough to roll into stars.

Stars of a yellowish Colour.

Take 4 oz. of gum-tragacanth or gum-arabick, pounded and sifted through a fine sieve, camphor dissolved

D

in

in brandy 2 oz. saltpetre 1 lb. sulphur $\frac{1}{2}$ lb. coarse powder of glass 4 oz. white amber 1 $\frac{1}{2}$ oz. orpiment 2 oz. Being well incorporated, make them into stars after the common method.

Stars of another Kind.

Take 1 lb. of camphor, and melt it in a pint of spirit of wine over a slow fire; then add to it 1 lb. of gum-arabick that has been dissolved; with this liquor mix 1 lb. of saltpetre, 6 oz. of sulphur, and 5 oz. of meal powder; and after you have stirred them well together, roll them into stars proportionable to the rockets for which you intend them.

Colours produced by the different Compositions.

As variety of fires adds greatly to a collection of works, it is necessary that every artist should know the different effect of each ingredient; for which reason, I shall here explain the colours they produce of themselves; and likewise how to make them retain the same when mixed with other bodies: as for example, sulphur gives a blue, camphor a white or pale colour, saltpetre a clear white, yellow amber a colour inclining to yellow, sal-armoniac a green, antimony a reddish, rosin a copper colour, and greek-pitch a kind of bronze or between red and yellow. All these ingredients are such as shew themselves in a flame, viz.

White Flame.

Saltpetre, sulphur, meal powder, and camphor; the saltpetre must be the chief part.

Blue Flame.

Meal powder, saltpetre, and sulphur vivum; sulphur must be the chief: or, meal powder, saltpetre, brimstone,

stone, spirit of wine, and oil of spike; but let the powder be the principal part.

Flame inclining to Red.

Saltpetre, sulphur, antimony, and greek-pitch; saltpetre the chief.

By the above method may be made various colours of fire, as the practitioner pleases; for, by making a few trials, he may cause any ingredient to be predominant in colour.

Ingredients that shew in Sparks when rammed in choaked Cases.

The set colours of fire produced by sparks are divided into 4 sorts, viz. the black, white, grey, and red: the black charges are composed of 2 ingredients, which are meal powder and charcoal; the white of 3, viz. saltpetre, sulphur, and charcoal; the grey of 4, viz. meal powder, saltpetre, brimstone, and charcoal; and the red of 3, viz. meal powder, charcoal, and saw dust.

There are, besides these 4 regular or set charges, 2 others, which are distinguished by the names of compound and brilliant charges; the compound being made of many ingredients, such as meal powder, saltpetre, brimstone, charcoal, saw dust, sea-coal, antimony, glass dust, brass dust, steel filings, cast iron, tanner's dust, &c. or any thing that will yield sparks; all which must be managed with discretion. The brilliant fires are composed of meal powder, saltpetre, brimstone, and steel dust; or with meal powder and steel filings only.

Cotton Quick-match

Is generally made of such cotton as is put in candles, of several sizes, from 1 to 6 threads thick, according to the pipes it is designed for, which pipe must

be large enough for the match, when made, to be pushed in easily without breaking it. Having doubled the cotton into as many threads as you think proper, coil it very lightly into a flat-bottomed copper or earthen pan; then put in the saltpetre and the liquor, and boil them about 20 minutes; after which coil it again into another pan, as in Fig. 4. and pour on it what liquor remains; then put in some meal powder, and press it down with your hands, till it is quite wet; afterwards place the pan before the wooden frame, Fig. 5. which must be suspended by a point in the centre of each end; and place yourself before the pan, tying the upper end of the cotton to the end of 1 of the sides of the frame.

When every thing is ready, you must have one to turn the frame round, while you let the cotton pass through your hands, holding it very lightly, and at the same time keeping your hands full of the wet powder; but if the powder should be too wet to stick to the cotton, put more in the pan, so as to keep a continual supply till the match is all wound up; you may wind it as close on the frame as you please, so that it does not stick together; when the frame is full, take it off the points, and sift dry meal powder on both sides the match, till it appears quite dry: in winter the match will be a fortnight before it is fit for use; when it is thoroughly dry, cut it along the outside of one of the sides of the frame, and tie it up in skains for use.

N. B. The match must be wound tight on the frames.

Ingredients for the Match.

Cotton 1 lb. 12 oz. saltpetre 1 lb. spirit of wine 2 quarts, water 3 quarts, isinglass 3 gills, and meal powder 10 lb. To dissolve 4 oz. of isinglass, take 3 pints of water.

SECT. III.—Sky-rocket Moulds.

AS the performance of rockets depends much on their moulds, it is requisite to give a definition of them and their proportions: They are made and proportioned by the diameter of their orifice, which are divided into ∞ parts: as Fig 6. represents a mould made by its diameter AB, its height from C to D is 6 diameters and 2 thirds; from D to E is the height of the foot, which is 1 diameter and 2 thirds; F the choak, or cylinder, whose height is 1 diameter and 1-3d; it must be made out of the same piece as the foot, and fit tight in the mould; G an iron pin that goes through the mould and cylinder, to keep the foot fast; H the nipple, which is $\frac{1}{2}$ a diameter high, and 2-3ds thick, and of the same piece of metal as the piercer I, whose height is $3\frac{1}{2}$ diameters, and at the bottom is 1 3d of the diameter thick, and from thence tapering to 1-6th of the diameter: the best way to fix the piercer in the cylinder, is to make that part below the nipple long enough to go quite through the foot, and rivet it at bottom. Fig. 7. is a former or roller for the cases, whose length, from the handle, is $7\frac{1}{2}$ diameters, and its diameter 2-3ds of the bore AB; 8. the end of the former, which is of the same thickness, and 1 diameter and 2-3ds long; the small part, which fits into the hole in the end of the roller when the case is pinching, is 1 6th and $\frac{1}{2}$ of the mould's diameter thick. Fig. 9. the first drift, which must be 6 diameters from the handle, and this as well as all other rammers must be a little thinner than the former, to prevent the facking of the paper, when you are driving in the charge: in the end of this rammer is a hole to fit over the piercer; the line K marked on this is 2 diameters and 1-3d from the handle; so that, when you are filling the rocket, this line appears at top of the case; you must then take the 2d rammer, 10. which
from

from the handle is 4 diameters; and the hole for the piercer is $1\frac{1}{2}$ diameter long. Fig. 11. is the short and solid drift which you use when you have filled the case as high as the top of the piercer.

Rammers must have a collar of brass at the bottom, to keep the wood from spreading or splitting; and that the same proportion be given to all moulds, from 1 oz. to 6 lb. I mentioned nothing concerning the handles of the rammers; however, if their diameter be equal to the bore of the mould, and 2 diameters long, it will be a very good proportion; but the shorter you can use them, the better; for the longer the drift, the less will be the pressure on the composition, by the blow given with the mallet.

Dimensions for Rocket Moulds, in which the Rockets are rammed solid.

Weight of rock- ets.	Length of the moulds with- out their feet.	Interior diameter of the moulds	Height of the nipples.
lb. oz.	Inches	Inches.	Inches
6 0	34,7	3,5	1,5
4 0	38,6	2,9	1,4
2 0	13,35	2,1	1,0
1 0	12,25	1,7	0,85
0 8	10,125	1,333 &c.	0,6
0 4	7,75	1,125	0,5
0 2	6,2	0,9	0,45
0 1	4,9	0,7	0,35
0 $\frac{1}{2}$	3,9	0,55	0,25
6 drams	3,5	0,5	0,225
4 drams	2,2	0,3	0,2

The diameter of the nipple must always be equal to that of the former.

I have omitted the thickness of the moulds, it being very immaterial, provided they are substantial and strong.

I would not advise those who make rockets for private amusement, to ram them solid, for it requires a very skillful hand, and an expensive apparatus for boring them, which will be shewn hereafter. Driving of rockets solid is the most expeditious method, but not so certain as ramming them over a piercer, which I have found by experience.

Moulds for Wheel Cases or Serpents.

Fig. 12. represents a mould, in which the cases are drove solid; L the nipple*, with a point† at top, which, when the case is filling, serves to stop the neck, and prevent the composition from falling out, which without this point it would do; and, in consequence, the air would get into the vacancy in the charge, and at the time of firing cause the case to burst. These sort of moulds are made of any length or diameter, according as the cases are required; but the diameter of the rollers must be equal to half the bore, and the rammers made quite solid.

To roll Rocket and other Cases.

Sky-rocket cases are to be made $6\frac{1}{2}$ of their exterior diameter long, and all other cases that are to be filled in moulds must be as long as the moulds, within half its interior diameter.

Rocket cases, from the smallest to 4 or 6 pound, are generally made of the strongest sort of cartridge paper,

* The nipple and cylinder to bear the same proportion as those for rockets.

† A round bit of brass, equal in length to the pick of the case, and flat at the top.

and

and rolled dry; but the large sort are made of pasted paste board. As it is very difficult to roll the ends of the cases quite even, the best way will be to keep a pattern of the paper for the different sorts of cases, which pattern should be somewhat longer than the case it is designed for, and on it marked the number of sheets required, which will prevent any paper being cut to waste: having cut your papers of a proper size, and the last sheet for each case with a slope at one end, so that when the cases are rolled it may form a spiral line round the outside, and that this slope may always be the same, let the pattern be so cut for a guide: before you begin to roll, fold down one end of the first sheet, so far that the fold will go 2 or 3 times round the former; then, on the double edge, lay the former with its handle off the table, and when you have rolled on the paper, within 2 or 3 turns, lay, on that part which is loose, the next sheet, and roll it all on.

Having thus done, you must have a smooth board, about 20 inches long, and equal in breadth to the length of the case; in the middle of this board must be a handle placed length-ways; under this board lay your case, and let one end of the board lie on the table; then press hard on it, and push it forwards, which will roll the paper very tight; do this 3 or 4 times before you roll on any more paper: this must be repeated every other sheet of paper, till the case is thick enough; but if the rolling board be drawn backwards, it will loosen the paper: you are to observe, when you roll on the last sheet, that the point of the slope be placed at the small end of the roller. Having rolled your case to fit the mould, push in the small end of the former F, about 1 diameter from the end of the case, and put in the end piece within a little distance of the former; then give the pinching cord one turn round the case, between the former and the end piece; at first pull easy, and keep moving the case, which will make the neck smooth, and without large wrinkles; when the cases are hard to choak, let each sheet of paper (except the first and last, in that part

part where the neck is formed) be a little moistened with water: immediately after you have struck the concave stroke, bind the neck of the case round with small twine, which must not be tied in a knot, but fastened with 2 or 3 hitches.

Having thus pinched and tied the case so as not to give way, put it into the mould without its foot, and with a mallet drive the former hard on the end piece, which will force the neck close and smooth; this done, cut the case to its proper length, allowing from the neck to the edge of the mouth half a diameter, which is = to the height of the nipple; then take out the former, and drive the case over the piercer with the long rammer, and the vent will be of a proper size. Wheel cases must be drove on a nipple with a point, to close the neck, and make the vent of the size required; which, in most cases, is generally $\frac{1}{4}$ of their interior diameter: as it is very oft difficult, when the cases are rolled, to draw the roller out, you may make a hole through the handle, and put in it a small iron pin, by which you may easily turn the former round, and pull it out. Fig. 17. shews the method of pinching cases; P a treddle, which, when pressed hard with the foot, will draw the cord tight, and force the neck as close as you please; Q a small wheel or pulley, with a groove round it for the cord to run in.

Cases are commonly rolled wet, for wheels and fixed pieces; and when they are required to contain a great length of charge, the method of making those cases is thus: Your paper must be cut as usual, only the last sheet must not be cut with a slope; having your paper ready, paste each sheet on one side; then fold down the first sheet as before directed, but be careful that the paste does not touch the upper part of the fold, for if the roller be wetted, it will tear the paper in drawing it out: in pasting the last sheet, observe not to wet the last turn or 2 in that part where it is to be pinched; for if that part be damp, the pinching cord will stick to it, and tear the paper; therefore, when you choak those cases,

cases, roll a bit of dry paper once round the case, before you put on the pinching cord; but this bit of paper must be taken off after the case is choaked. The rolling board, and all other methods, according to the former directions for the rolling and pinching of cases, must be used to these as well as all other cases.

To make Tourbillon Cases.

Those sort of cases are generally made about 8 diameters long, but if very large, 7 will be sufficient: tourbillons will answer very well from 4 oz. to 2 lb. but when larger there is no certainty. The cases are best rolled wet with paste, and the last sheet must have a strait edge, so that the case may be all of a thickness: when you have rolled your cases, after the manner of wheel cases, pinch them at one end quite close; then, with the rammer, drive the ends down flat, and afterwards ram in about 1-3d of a diameter of dried clay. The diameter of the former for these cases must be the same as for sky rockets.

N.B. Tourbillons are to be rammed in moulds without a nipple, or in a mould without its foot.

Ballóon Cases, or Paper Shells.

First you must have an oval former turned of smooth wood; then paste a quantity of brown or cartridge paper, and let it lie till the paste has quite soaked through; this done, rub the former with soap or grease, to prevent the paper from sticking to it; then lay the paper on in small slips, till you have made it 1-3d of the thickness of the shell intended; having thus done, set it to dry, and when dry, cut it round the middle, and the 2 halves will easily come off; but observe, when you cut, to leave about 1 inch not cut, which will make the halves join much better than if quite separated; when you have some ready to join, place the halves even together, and paste a slip of paper round the opening to hold them together,

together, and let that dry; then lay on paper all over as before, every where equal, excepting that end which goes downwards in the mortar, which may be a little thicker than the rest; for that part which receives the blow from the powder in the chamber of the mortar consequently requires the greatest strength: when the shell is thoroughly dry, burn a round vent at top, with square iron, large enough for the fuze: this method will do for ballóons from 4 inches 2-5ths, to 8 inches diameter; but if they are larger, or required to be thrown a great height, let the first shell be turned of elm, instead of being made of paper.

For a ballóon of 4 inches 2-5ths, let the former be 3 inches 1-8th diameter, and $5\frac{1}{2}$ inches long. For a ballóon of $5\frac{1}{2}$ inches the diameter of the former must be 4 inches, and 8 inches long. For a ballóon of 8 inches, let the diameter of the former be 5 inches and 15-16ths, and 11 inches 7-8ths long. For a 10-inch ballóon, let the former be 7 inches 3-16ths diameter, and $14\frac{1}{4}$ inches long. The thickness of a shell for a ballóon of 4 inches 2-5ths, must be $\frac{1}{2}$ inch. For a ballóon of $5\frac{1}{2}$ inches let the thickness of the paper be 5-8ths of an inch. For an 8-inch balloon, 7-8ths of an inch. And for a 10 inch ballóon, let the shell be 1 inch 1-8th thick.

Shells that are designed for stars only, may be made quite round, and the thinner they are at the opening, the better; for if they are too strong, the stars are apt to break at the bursting of the shell: when you are making the shell, make use of a pair of calibres, or a round gauge, so that you may not lay the paper thicker in one place than another; and also to know when the shell is of a proper thickness. Ballóons must always be made to go easy into the mortars.

Mixing Compositions.

The performance of the principal part of fireworks depends much on the compositions being well mixed; therefore

therefore great care must be taken in this part of the work, particularly for the compositions for sky rockets. When you have 4 or 5 pounds of ingredients to mix, which is a sufficient quantity at a time (for a larger proportion will not do so well) first put the different ingredients together; then work them about with your hands, till you think they are pretty well incorporated: after which put them into a lawn sieve with a receiver and top to it; and if, after it is sifted, any remains that will not pass through the sieve, grind it again till fine enough; and if it be twice sifted, it will not be amiss: but the compositions for wheels and common works are not so material, nor need not be so fine. But in all fixed works, from which the fire is to play regular, the ingredients must be very fine, and great care taken in mixing them well together; and observe that, in all compositions wherein are steel or iron filings, the hands must not touch; nor will any works, which have iron or steel in their charge, keep long in damp weather, without being properly prepared, according to the following directions.

To preserve Steel or Iron Filings.

It sometimes may happen, that fireworks may be required to be kept a long time, or sent abroad; neither of which could be done with brilliant fires, if made with filings unprepared; for this reason, that the saltpetre being of a damp nature, it causes the iron to rust, the consequence of which is, that when the works are fired, there will appear but very few brilliant sparks, but instead of them a number of red and drossy sparks; and besides, the charge will be so much weakened, that if this was to happen to wheels, the fire will hardly be strong enough to force them round: but to prevent such accidents, prepare your filings thus. Melt in a glazed earthen pan some brimstone over a slow fire, and when melted throw in some filings; which keep stirring about till they are covered with brimstone: this you must do
while

while it is on the fire; then take it off, and stir it very quick till cold, when you must roll it on a board with a wooden roller, till you have broke it as fine as corn powder; after which sift from it as much of the brimstone as you can. There is another method of preparing filings, so as to keep 2 or 3 months in winter; this may be done by rubbing them between the strongest sort of brown paper, which before has been moistened with linseed oil.

N. B. If the brimstone should take fire, you may put it out, by covering the pan close at top: it is not of much signification what quantity of brimstone you use, so that there is enough to give each grain of iron a coat; but as much as will cover the bottom of a pan of about 1 foot diameter, will do for 5 or 6 pound of filings, or cast iron for gerbes.

To drive or ram Sky Rockets, &c.

Rockets drove over a piercer must not have so much composition put in them at a time, as when drove solid, for the piercer, taking up great part of the bore of the case, would cause the rammer to rise too high; so that the pressure of it would not be so great on the composition, nor would it be drove every where equal: to prevent which, observe the following rule; that for those rockets, that are rammed over a piercer, let the ladle* hold as much composition as, when drove, will raise the drift $\frac{1}{2}$ the interior diameter of the case, and for those drove solid to contain as much as will raise it $\frac{1}{2}$ the exterior diameter of the case: ladles are generally made to go easy in the case, and the length of the scoop about $1\frac{1}{2}$ of its own diameter.

The charge of rockets must always be drove 1 diameter above the piercer, and on it must be rammed 1-3d of a diameter of clay, through the middle of which bore a small hole to the composition, that, when the charge is burnt to the top, it may communicate its fire, through

* A copper scoop with a wooden handle.

the hole, to the stars in the head: great care must be taken, to strike with the mallet, and with an equal force, the same number of strokes to each ladle-full of charge; otherwise the rockets will not rise with an uniform motion, nor will the composition burn equal and regular; for which reason they cannot carry a proper tail, for it will break before the rocket has got half way up; instead of reaching from the ground to the top, where the rocket breaks and disperses the stars, rains, or whatever is contained in the head. When you are ramming, keep the drift constantly turning or moving; and when you use the hollow rammers, knock out of them the composition now and then, or the piercer will split them: to a rocket of 4 oz. give to each ladle-full of charge 16 strokes: to a rocket of 1 lb. 28: to a 2-pounder, 36: to a 4-pounder, 42: and to a 6-pounder, 56: but rockets of a larger sort cannot be drove well by hand, but must be rammed with a machine made in the same manner as those for driving piles, which are so very common to be seen, that I shall omit a description.

The method of ramming of wheel cases, or any other sort, in which the charge is drove solid, is much the same as sky rockets; for the same proportion may be observed in the ladle, and the same number of strokes given, according to their diameters, all cases being distinguished by their diameters: in this manner, a case whose bore is equal to a rocket of 4 oz. is called a 4-oz. case, and that which is equal to an 8-oz. rocket an 8-oz. case, and so on, according to the different rockets.

Having taught the method of ramming cases in moulds; we shall here say something concerning those filled without moulds; which method, for strong pasted cases, will do extremely well, and save the expence of making so many moulds. The reader must here observe, when he fills any sort of cases, to place the mould on a perpendicular block of wood, and not on any place that is hollow; for we have found by experience, that when cases were rammed on driving benches, which were formerly

formerly used, the works frequently miscarried, on account of the hollow resistance of the benches, which oft jarred and loosened the charge in the cases; but this accident has never happened since the driving blocks* have been used.

When cases are to be filled without moulds, proceed thus; have some nipples made of brass or iron, of several sorts and sizes, in proportion to the cases, and to screw or fix in the top of the driving block; when you have fixed in a nipple, make, at about $1\frac{1}{2}$ inch from it, a square hole, in the block, 6 inches deep and 1 inch diameter; then have a piece of wood, 6 inches longer than the case intended to be filled, and 2 inches square; on 1 side of it cut a groove almost the length of the case, whose breadth and depth must be sufficient to cover near $\frac{1}{2}$ the case; then cut the other end to fit the hole in the block, but take care to cut it so that the groove may be of a proper distance from the nipple: this half mould being made and fixed tight in the block, cut, in another piece of wood nearly of the same length as the case, a groove of the same dimensions as that in the fixed piece; then put the case on the nipple, and with a cord tie it and the 2 half moulds together, and your case will be ready for filling.

The dimensions of the above described half moulds, are proportionable for cases of 8 ounces; but notice must be taken, that they differ in size in proportion to the cases.

Note, the clay, mentioned in this article, must be prepared after this manner; get some clay, in which there is no stones nor sand, and bake it in an oven till quite dry; then take it out and beat it to a powder, and afterwards sift it through a common hair sieve, and it will be fit for use.

* A piece of hard wood in the form of an anvil block.

Proportion of Mallets.

The best wood for mallets is dry beech. I would have every practitioner know, that if he uses a mallet of a moderate size, in proportion to the rocket, according to his judgement, and if that rocket succeeds, he may depend on the rest, by using the same mallet; yet it will be necessary that cases of different sorts be drove with mallets of different sizes.

The following proportion of the mallets for rockets of any size, from 1 oz. to 6 lb. may be observed; but as rockets are seldom made less than 1 oz. or larger than 6 lb. I shall leave the management of them to the curious; but all cases under 1 oz. may be rammed with an oz. rocket mallet. Your mallets will strike more solid, by having their handles turned out of the same piece as the head, and made in a cylindrical form: let their dimensions be worked by the diameters of the rockets: for example; let the thickness of the head be 3 diameters, and its length 4, and the length of the handle 5 diameters, whose thickness must be in proportion to the hand.

Proportion of Sky Rockets, and Manner of heading them.

Fig. 13. a rocket compleat without its stick, whose length from the neck is 5 diameters 1-6th; the cases should always be cut to this length after they are filled; M the the head, which is 2 diameters high, and 1 diameter 1-6th $\frac{1}{2}$ in breadth; N the cone or cap, whose perpendicular height must be 1 diameter 1-3-d. Fig. 14. the collar to which the head is fixed; this is turned out of deal or any light wood, and its exterior diameter must be equal to the interior diameter of the head; 1-6th will be sufficient for its thickness, and round the outside edge must be a groove; the interior diameter of the collar must not be quite so wide as the exterior diameter of

of the rocket; when this is to be glued on the rocket, you must cut 2 or 3 rounds of paper off the case, which will make a shoulder for it to rest upon. Fig. 15, a former for the head: 2 or 3 rounds of paper well pasted will be enough for the head, which, when rolled, put the collar on that part of the former marked O, which must fit the inside of it; then, with the pinching cord pinch the bottom of the head into the groove, and tie it with small twine. Fig. 16, a former for the cone. To make the caps, cut your paper in round pieces, equal in diameter to twice the length of the cone you intend to make; which pieces being cut into halves, will make 2 caps each, without wasting any paper; having formed the caps, paste over each of them a thin white paper, which must be a little longer than the cone, so as to project about $\frac{1}{2}$ an inch below the bottom: this projection of paper, being notched and pasted, serves to fasten the cap to the head.

When you load the heads of your rockets with stars, rains, serpents, crackers, scrolls, or any thing else, according to your fancy; remember always to put a ladle-full of meal powder into each head, which will be enough to burst the head, and disperse the stars, or whatever it contains: when the heads are loaded with any sort of cases, let their mouths be placed downwards; and after the heads are filled, paste on the top of them a piece of paper, before you put on the caps. As the size of stars oft differ, it would be needless to give an exact number for each rocket, but this rule may be observed, that the heads may be nearly filled with whatever they are loaded.

Decorations for Sky Rockets.

Sky rockets bearing the pre-eminence of all fireworks, it will not be improper to treat of their various kinds of decorations, which are directed according to fancy; some are headed with stars of different sorts, such as tailed, brilliant, white, blue and yellow stars, &c. some with gold and silver rain; others with serpents, crackers, fire-

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scrolls,

scrolls, marrons; and some with small rockets, and many other devices, as the maker pleases.

Dimensions and Poise of Rocket Sticks.

Weight of the rocket.		Length of the stick.		Thickness at top.	Breadth at top.	Square at bottom.	Poise from the point of the cone.	
lb.	oz.	ft.	in.	Inches.	Inches	Inches	ft.	in.
6	0	14	0	1,5	1,85	0,75	4	1,5
4	0	12	10	1,25	1,40	0,625	3	9,
2	0	9	4	1,125	1,	0,525	2	9,
1	0	8	2	0,725	0,80	0,375	2	1,
	8	6	6	0,5	0,70	0,25	1	10,5
	4	5	3	0,3750	0,55	0,35	1	8,5
	2	4	1	0,3	0,45	0,15	1	3,
	1	3	6	0,25	0,35	0,10	1	0,
	$\frac{1}{2}$	2	4	0,125	0,20	0,16	8	0,
	$\frac{1}{4}$	1	10 $\frac{1}{2}$	0,1	0,15	0,5	5	0,5

The last column on the right, in the above table, expresses the distance from the top of the cone, where the stick, when tied on, should balance the rocket, so as to stand in an equilibrium on one's finger, or the edge of a knife. The best wood for the sticks is dry deal, made thus; when you have cut and planed the sticks according to the dimensions given in the table, cut on 1 of the flat sides at top, a groove the length of the rocket, and as broad as the stick will allow; then on the opposite flat side, cut 2 notches for the cord, which ties on the rocket, to lay in; 1 of these notches must be near the top of the stick, and the other facing the neck of the rockets; the distance between these notches may easily be known, for the top of the stick should always touch the head of the rocket. When your rockets and sticks are ready, lay the rockets in the grooves in the sticks, and

and tie them on. Those who, merely for curiosity, may chuse to make rockets of different sizes, to what I have expressed in the table of dimensions, may find the length of their sticks, by making them for rockets, from $\frac{1}{2}$ oz. to 1 lb. 60 diameters of the rocket long; and for rockets above 1 lb. 50 or 52 diameters will be a good length; their thickness at top may be about $\frac{1}{2}$ a diameter, and their breadth a very little more; their square at bottom is generally equal to $\frac{1}{2}$ the thickness at top. But, although the dimensions of the sticks be very nicely observed, you must depend only on their balance: for, without a proper counterpoise, your rockets, instead of mounting perpendicularly, will take an oblique direction, and fall to the ground before they are burnt out.

Boring Rockets which have been drove solid.

Plate 2, Fig. 18, represents the plan of an apparatus, or lathe, for boring of rockets; A the large wheel which turns the small one B, that works the reammer C: these reammers are of different sizes according to the rockets; they must be of the same diameter as the top of the bore intended, and continue that thickness a little longer than the depth of the bore required, and their points must be like that of an auger; the thick end of each reammer must be made square, and all of the same size, so as to fit into one socket, wherein they are fastened by a screw D: E the guide for the reammer, which is made to move backwards and forwards; so that, after you have marked the reammer $3\frac{1}{2}$ diameters of the rocket from the point, set the guide, allowing for the thickness of the fronts of the rocket boxes; and the neck and mouth of the rocket, so that when the front of the large box is close to the guide, the reammer may not go too far up the charge. F, boxes for holding the rockets, which are made so as to fit one in another; their sides must be equal in thickness to the difference of the diameters of the rockets, and their interior diameters equal to the exterior diameters of the rockets. To prevent the rockets turning round while

E 2

boring

boring, a piece of wood must be placed against the end of the box in the inside, and pressed against the tail of the rocket; this will also hinder the reammer from forcing the rocket backwards. G, a rocket in the box. H, a box that slides under the rocket boxes to receive the borings from the rockets, which fall through holes made on purpose in the boxes; these holes must be just under the mouth of the rocket, one in each box, and all to correspond with each other.

Fig. 19, is a front view of the large rocket box. I, an iron plate, in which are holes of different sizes, through which the reammer passes; this plate is fastened with a screw in the centre, so that when you change the reammer, you turn the plate round, but always let the hole you are going to use be at the bottom: the fronts of the other boxes must have holes in them to correspond with them in the plate. K, the lower part of the large box, which is made to fit the inside of the lathe, that all the boxes may move quite steady.

Fig. 20, is a perspective view of the lathe. L, the guide for the reammer, which is set by the screw at bottom.

Fig. 21, a view of the front of the guide facing the reammer. M, an iron plate, of the same dimensions as that on the front of the box, and placed in the same direction, and also to turn on a screw in the centre. N, the rocket box, which slides backwards and forwards: when you have fixed a rocket in the box, push it forwards against the reammer; and when you think the scoop of the reammer is full, draw the box back, and knock out the composition; this you must do till the rocket is bored, or it will be in danger of taking fire; and if you bore in a hurry, wet the end of the reammer now and then with oil to keep it cool.

Having bored a number of rockets, you must have taps of different sorts according to the rockets. These taps are a little longer than the bore, but when you use them mark them $3\frac{1}{2}$ diameters from the point, allowing for the thickness of the rocket's neck; then, holding

the

the rocket in one hand, you tap it with the other. To explain these taps, I have represented 1 by Fig. 22. They are made in the same proportion as the fixed piercers, and are hollowed their whole length.

Hand Machine used for boring of Rockets instead of a Lathe.

These sort of machines answer very well, but not so expeditious as the lathe, nor are they so expensive to make; they may be worked by 1 man; but the lathe will require 3. Fig. 23, represents the machine. O, the rocket boxes, which are to be fixed, and not to slide as those in the lathe. P Q are guides for the reamers, that are made to slide together, as the reammer moves forward: the reammers for these sort of machines must be made of a proper length, allowing for the thickness of the front of the boxes, and the length of the mouth and neck of the case: on the square end of these reammers, must be a round shoulder of iron, to turn against the outside of the guide Q, by which means the guides are forced forwards. R, the stock which turns the reammer, and while turning must be pressed towards the the rocket, by the body of the man who works it; all the reammers are to be made to fit 1 stock. This machine as well as the lathe is made by the scale in the same place.

To make large Gerbes.

Fig. 24, represents a wooden former; 25, a gerbe complete, with its foot or stand. The cases for gerbes are made very strong, on account of the strength of the composition; which, when fired, comes out with great velocity; therefore, to prevent their bursting, the paper should be pasted, and the cases made as thick at the top as at the bottom; they should also have very long necks, for this reason; first, that the particles of iron will have more time to be heated, by meeting with greater resist-

in getting out, than with a short neck, which would be burnt too wide before the charge be consumed, and spoil the effect: Secondly, that with long necks the stars will be thrown to a great height, and will not fall before they are spent, or spread too much; but, when made to perfection will rise and spread in such a manner as to form exactly a wheat-sheaf.

In the ramming of gerbes, there will be no need of a mould, the cases being sufficiently strong to support themselves; but you are to be careful, before you begin to ram, to have a piece of wood made to fit in the neck; for if this be not done, the composition will fall into the neck, and leave a vacancy in the case, which, as I said before, will cause the case to burst so soon as the fire arrives at the vacancy: you must likewise observe, that the first ladle of charge, or 2, if you think proper, be of some weak composition. When the case is filled, take out the piece of wood, and fill the neck with some slow charge. Gerbes are generally made about six diameters long, from the bottom to the top of the neck; their bore must be 1-5th narrower at top than at bottom. The neck S is 1-6th diameter and $\frac{3}{4}$ long. T, a wooden foot or stand, on which the gerbe is fixed. This may be made with a choak or cylinder, 4 or 5 inches long, to fit the inside of the case, or with a hole in it to put in the gerbe; both these methods will answer the same. Gerbes produce a most brilliant fire, and are very beautiful when a number of them are fixed in the front of a building, or a collection of fireworks.

N. B. Gerbes are made by their diameters, and their cases at bottom $\frac{1}{4}$ thick. The method of finding the interior diameter of a gerbe is thus: Supposing you would have the exterior diameter of the case, when made, to be 5 inches, then, by taking 2-4ths for the sides of the case, there will remain $2\frac{1}{2}$ inches for the bore, which will be a very good size. These sort of gerbes should be rammed very hard.

Small Gerbes, or White Fountains,

May be made of 4, 8 oz. or 1 lb. cases, pasted and made very strong, of what length you please; but, before you fill them, drive in dry clay 1 diameter of their orifice high; and, when you have filled a case, bore a vent through the centre of the clay to the composition; the common proportion will do for the vent, which must be primed with a slow charge. These sort of cases, without the clay, may be filled with Chinese fire.

To make PASTE-board and Paper Mortars.

Fig. 26, a former, and 27, an elm foot for the mortar; 28, a mortar complete; these mortars are best when made with pasteboard, well pasted before you begin; or, instead of paste, you may use glue. For a coehorn mortar, which is 4 inches 2-5ths diameter, roll the pasteboard on the former 1-6th of its diameter thick; and, when dry, cut one end smooth and even; then nail and glue it on the upper part of the foot; when done, cut off the paste-board at top, allowing for the length of the mortar $2\frac{1}{2}$ diameters from the mouth of the powder chamber; then bind the mortar round with a strong cord wetted with glue. U, the bottom part of the foot, is 1 diameter 2-3ds broad, and 1 diameter high; and that part which goes into the mortar is 2-3ds of its diameter high. W, is a copper chamber for powder, made in a conical form, and is 1-3d of the diameter wide, $1\frac{1}{2}$ of its own diameter long; in the centre of the bottom of this chamber, make a small hole a little way down the foot; this hole must be met by another of the same size, made in the side of the foot, as is shewn in Fig. 28. If these holes are made true, and a copper pipe fitted into both, the mortar when loaded will prime itself, for the powder will naturally fall to the bottom of the first hole; then by putting a bit of quick-match in the side hole, your mortar will be ready to be fired.

Mortars of $5\frac{1}{2}$, 8, and 10 inches diameter, may be made of paper, or paste-board, by the above method, and in the same proportion; but if larger, it will be best to have them made of brass. N. B. The copper chamber must have a small rim round its edge with holes in it, for screws to make it fast in the foot.

SECT. IV.—To load Air Ballóons, with the Number of Stars, Serpents, Snakes, Rain-falls, &c. in Shells of each Nature.

BALLOONS being in great esteem, by admirers of fire works, I shall give a full description of them.

When you fill your shells, you must first put in the serpents, rains, stars, &c. or whatever they are composed of; then the blowing powder; but the shells must not be quite filled; all those things must be put in at the fuze hole; but marrons, being too large to go in at the fuze hole, must be put in before the inside shell be joined. When the shells are loaded, glue and drive in the fuzes very tight. Of these fuzes we shall say more hereafter; but shall here give the diameter of the fuze hole in ballóons of each nature, which are,—For a coehorn ballóon, let the diameter of the fuze hole be $\frac{7}{8}$ ths of an inch. For a royal ballóon, which is near $5\frac{1}{2}$ inches diameter, make the fuze hole 1 inch $\frac{1}{8}$ th diameter. For an 8-inch ballóon, 1 inch $\frac{3}{8}$ ths; and for a 10-inch ballóon, 1 inch $\frac{5}{8}$ ths.

Having proceeded thus far with the directions of loading ballóons, I shall in the second place give an account of the quantities and number of each article proper for shells of each nature; but it is to be observed, that air-ballóons are divided into 4 sorts, viz. first, illuminated ballóons; second, ballóons of serpents; third, ballóons of

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of reports, marrons, and crackers; and fourth, compound ballóons.

Coehorn Ballóon illuminated.

Meal	} powder {	—	—	—	oz.
Corn		—	—	—	1 $\frac{1}{2}$
Powder for the mortar		—	—		0 $\frac{1}{2}$
					2

Length of the fuze composition $\frac{3}{4}$ of an inch; 1 oz. drove or rolled stars, as many as will nearly fill the shell.

Coehorn Ballóon of Serpents.

Meal	} powder {	—	—	—	oz.
Corn		—	—	—	1 $\frac{1}{4}$
Powder for the mortar		—	—		1
					2 $\frac{1}{4}$

Length of the fuze composition 13 16ths of an inch. $\frac{1}{2}$ oz. cafes drove 3 diameters and bounced 3 diameters; and $\frac{1}{2}$ oz. cafes drove 2 diameters and bounced 4; of each an equal quantity, and as many of them as will fit in easily, placed head to tail.

Coehorn Ballóon of Crackers and Reports.

Meal	} powder {	—	—	oz.
Corn		—	—	1 $\frac{1}{4}$
Powder for the mortar		—		0 $\frac{3}{4}$
				2

Length of the fuze composition $\frac{3}{4}$ of an inch. Reports 4, and crackers of 6 bounces, as many as will fill the shell.

Compound

Compound Coehorn Ballóons.

			oz.	dr.
Meal	} powder {	—	1	4
Corn		—	0	12
Powder for the mortar		—	2	4

Length of the fuze composition 13 16ths of an inch.
 $\frac{1}{2}$ oz. cafes drove 3 $\frac{1}{2}$ diameters and bounced 2, sixteen;
 $\frac{1}{2}$ oz. cafes drove 4 diameters and not bounced, 10. Blue
 strung stars, 10. Rolled stars as many as will complete
 the ballóón.

Royal Ballóons illuminated.

			oz.	dr.
Meal	} powder {	—	1	8
Corn		—	0	12
Powder for the mortar		—	3	0

Length of the fuze composition 15 16ths of an inch.
 2 oz. strung stars, 34: Rolled stars as many as the shell
 will contain, allowing room for the fuze.

Royal Ballóons of Serpents.

			oz.	dr.
Meal	} powder {	—	1	0
Corn		—	1	8
Powder for the mortar		—	3	8

Length of the fuze composition 1 inch. 1 oz. cafes
 drove 3 $\frac{1}{2}$ and 4 diameters, and bounced 2, of each an
 equal quantity, sufficient to load the shell.

Royal

Royal Ballóons with Crackers and Mar- rons.

				oz.	dr.
Meal	} powder {	_____	_____	1	8
Corn		_____	_____	1	4
Powder for firing the mortar		_____		3	0

Length of the fuze composition 14 16ths of an inch ; reports 12, and completed with crackers of 8 bounces.

Compound Royal Ballóons.

			oz.	dr.
Meal	} Powder {	_____	1	5
Corn		_____	1	6
Powder for the mortar		_____	3	12

Length of the fuze composition 1 inch. $\frac{1}{2}$ oz. cafes drove and bounced 2 diameters, 8. 2 ounce cafes filled 3-8ths of an inch with star composition, and bounced 2 diameters, 8. Silver rain-falls, 10. 2 oz. tailed stars, 16. Rolled brilliant stars, 30. If this should not be sufficient to load the shell, you may complete it with gold rain-falls.

Eight-inch Ballóons illuminated.

			oz.	dr.
Meal	} powder {	_____	2	8
Corn		_____	1	4
Powder for the mortar		_____	9	0

Length of the fuze composition 1 inch 1 8th. 2 oz. drove stars, 48. 4 oz. cafes drove with star composition 3 8ths of an inch, and bounced 3 diameters, 12 ; and the ballóon completed with 2 oz. drove brilliant stars.

Eight

Eight-inch Ballóons of Serpents.

			oz.	dr.
Meal	} powder {	_____	2	0
Corn		_____	2	0
Powder for the mortar		_____	9	8

Length of the fuze composition 1 inch 3 16ths. 2 oz. cases drove 1 $\frac{1}{2}$ diameter, and bounced 2; and 1 oz. cases drove 2 diameters, and bounced 2 $\frac{1}{2}$; of each an equal quantity, sufficient for the shell.

N. B. The star composition drove in bounced cases, must be managed thus; first, the cases must be pinched close at 1 end, then the corn powder put in for a report, and the case pinched again close to the powder, only leaving a small vent for the star composition, which is drove at top, to communicate to the powder at the bounce end.

REMARKS.

Ballóons filled with crackers, reports, and marrons, make no great show of themselves, nor are they very pleasing to the eye, for they represent nothing more than a number of pale white flashes, followed by a variety of reports; which all together make but a very indifferent appearance, when fired with illuminated ballóons, which are so beautiful and brilliant, as to give such lustre as will dazzle the eyes of the spectators for some time. On this consideration, I do not think it worth while loading shells of a large nature with things that afford so little pleasure; but they have a pretty good effect in royal shells, when thrown among a number of air works, such as pots des brins or flights of rockets, in order to alarm the people with a thundering in the air. For they will not know from whence the reports came, if fired exactly at the same time with the other works, and the fuze made to carry a small fire. But if any one thinks proper to make

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make large ballóons of this sort, it is only observing a proportion of the blowing and firing powder, and the length of the fuze, for shells of the same dimensions as those you intend to make. These kind of ballóons are lighter than any other, by reason of the crackers being light, and not lying close in the shells. It must be observed, when you fire light ballóons, not to put so much powder in the mortar as for heavy.

Compound 8-inch Ballóons.

		oz. dr.
Meal	} powder {	2 8
Corn	}	1 12
Powder for the mortar		9 4

Length of the fuze composition 1-8th. 4 oz. cafes drove with star composition 3-8ths of an inch, and bounced 3 diameters, 16. 2 oz. tailed stars, 16. 2 oz. drove brilliant stars, 12. Silver rain-falls, 20. 1 oz. drove blue stars, 20: and 1 oz. cafes drove and bounced 2 diameters, as many as will fill the shell.

Another of 8 inches.

		oz. dr.
Meal	} powder {	2 8
Corn	}	1 12
Powder for the mortar		9 4

Length of the fuze composition 1 inch 1 8th; crackers of 6 reports, 10. Gold rains, 14. 2 oz. cafes drove with star composition 3 8ths of an inch, and bounced 2 diameters, 16. 2 oz. tailed stars, 16. 2 oz. drove brilliant stars, 12. Silver rains, 10. 1 oz. drove blue stars, 20: and 1 oz. cafes drove with a brilliant charge 2 diameters and bounced 3, as many as the shell will hold.

Another

Another of 8 inches.

		oz.	dr.
Meal	} powder {	2	12
Corn		2	0
Powder for the mortar		9	0

Length of the fuze composition 1 inch 1 16th. Crackers of 6 reports, 10. Gold rains, 20. 2 oz. cafes drove with star composition $\frac{1}{2}$ an inch, and bounced 2 diameters, 16. 2 oz. drove brilliant stars, 2 oz. drove blue stars, 2 oz. drove coloured stars, 2 oz. drove tailed stars, large strung stars, and rolled stars, of each an equal quantity, sufficient for the ballóon.

A compound 10-inch Ballóon.

		oz.	dr.
Meal	} powder {	3	4
Corn		2	8
Powder for the mortar		12	8

Length of the fuze composition 15 16ths of an inch. 1 oz. cafes drove and bounced 3 diameters, 16. Crackers of 8 reports, 12. 4 oz. cafes drove $\frac{1}{2}$ an inch with star composition, and bounced 2 diameters, 14. 2 oz. cafes drove with brilliant fire 1 $\frac{1}{4}$ diameter, and bounced 2 diameters, 16. 2 oz. drove brilliant stars, 30. 2 oz. drove blue stars, 30. Gold rains, 20. Silver rains 20. After all these are put in, fill the remainder of the case with tailed and rolled stars.

Ten-inch Ballóon of 3 changes.

		oz.	dr.
Meal	} powder {	3	0
Corn		3	2
Powder for the mortar		13	0
Length			

Length of the fuze composition 1 inch. The shell must be loaded with 2 oz. cases, drove with star composition $\frac{1}{4}$ of an inch, and on that 1 diameter of gold fire, then bounced 3 diameters; or with 2 oz. cases first filled 1 diameter with gold-fire, then $\frac{1}{4}$ of an inch with star composition, and on that 1 diameter and $\frac{1}{4}$ of brilliant fire. These cases must be well secured at top of the charge, lest they should take fire at both ends; but their necks must be larger than the common proportion.

To make Ballóon Fuzes.

Fuzes for air ballóons are sometimes turned out of dry beech, with a cup at top, to hold the quick-match, as you see in Plate II. Fig. 28, but if made with pasted paper, they will do as well: the diameter of the former for fuzes for coehorn ballóons, must be $\frac{1}{2}$ an inch; for a royal fuze, $\frac{5}{8}$ ths of an inch; for an 8-inch fuze, $\frac{3}{4}$ of an inch; and for a 10-inch fuze, $\frac{7}{8}$ ths of an inch. Having rolled your cases, pinch and tie them almost close at one end; then drive them down, and let them dry; before you begin to fill them, mark, on the outside of the case, the length of charge required, allowing for the thickness of the bottom; and when you have rammed in the composition, take 2 pieces of quick-match, about 6 inches long, and lay one end of each on the charge, and then a little meal powder, which ram down hard; the loose ends of the match double up into the top of the fuze, and cover it with a paper cap to keep it dry. When you put the shells in the mortars, uncap the fuzes, and pull out the loose ends of the match, and let them hang on the sides of the ballóons. The use of the match is, to receive the fire from the powder in the chamber of the mortar, in order to light the fuze: the shell being put in the mortar with the fuze uppermost, and exactly in the centre; sprinkle over it a little meal-powder, and it will be ready to be fired. Fuzes made of wood must be longer than those of paper, and not bored quite through, but left solid about $\frac{1}{2}$ an inch at bottom; and when

when you use them, saw them off to a proper length, measuring the charge from the cup at top.

Tourbillons.

Having filled some cases within about $1\frac{1}{2}$ diameter, drive in a ladle-full of clay, then pinch their ends close, and drive them down with a mallet; when done, find the centre of gravity of each case, where you nail and tie a stick, which should be $\frac{1}{2}$ an inch broad at the middle, and run a little narrower to the ends: these sticks must have their ends turned upwards, so that the cases may turn horizontally on their centres: at the opposite sides of the cases, at each end, bore a hole close to the clay with a gimblet, the size of the neck of a common case of the same nature; from these holes draw a line round the case, and at the under part of the case bore a hole, with the same gimblet, within $\frac{1}{2}$ a diameter of each line towards the centre, then from one hole to the other draw a right line. This line divide into 3 equal parts, and at X and Y, Fig. 29, Plate III. bore a hole, then from these holes to the other 2, lead a quick-match, over which paste a thin paper. Fig. 30 represents a tourbillon as it should lie to be fired, with a leader from one side hole A, to the other B. When you fire tourbillons, lay them on a smooth table, with their sticks downwards, and burn the leader through the middle with a port fire. They should spin 3 or 4 seconds on the table before they rise, which is about the time the composition will be burning, from the side holes to those at bottom.

To tourbillons may be fixed reports, in this manner: in the centre of the case at top, make a small hole, and in the middle of the report make another; then place them together, and tie on the report, and with a single paper secure it from fire: this done, your tourbillon is completed. By this method you may fix on tourbillons, small cones of stars, rains, &c. but be careful not to load them too much. $1\frac{1}{8}$ th of an inch will be enough for the thickness of the sticks, and their length equal to that of the cases.

To

To make Mortars to throw Aigrettes, and to load and fire them.

Mortars to throw aigrettes are generally made of paste-board, of the same thickness as ballón mortars, and $2\frac{1}{2}$ diameters long in the inside from the top of the foot: the foot must be made of elm without a chamber, but flat at top, and in the same proportion as those for ballón mortars; these mortars must also be bound round with cord as before mentioned: sometimes 8 or 9 of these mortars, of about 3 or 4 inches diameter, are bound all together so as to appear but 1; but when they are made for this purpose, the bottom of the foot must be of the same diameter as the mortars, and only $\frac{1}{2}$ a diameter high. Your mortars being bound well together, fix them on a heavy solid block of wood: to load these mortars, first put on the inside bottom of each, a piece of paper, and on it spread $1\frac{1}{2}$ oz. of meal and corn powder mixed; then tie your serpents up in parcels with quick-match, and put them in the mortar with their mouths downwards; but take care the parcels do not fit too tight in the mortars, and that all the serpents have been well primed with powder wetted with spirit of wine: on the top of the serpents in each mortar lay some paper or tow; then carry a leader from one mortar to the other all round, and then from all the outside mortars into that in the middle: these leaders must be put between the cases and the sides of the mortar, down to the powder at bottom: in the centre of the middle mortar fix a fire-pump, or brilliant fountain, which must be open at bottom, and long enough to project out of the mouth of the mortar; then paste paper on the tops of all the mortars.

Mortars thus prepared are called a Nest of Serpents, as represented by Fig. 31. When you would fire these mortars, light the fire-pump C, which when consumed will communicate to all the mortars at once, by means of the leaders. For mortars of 6, 8, or 10 inches dia-

F
meter,

meter, the serpents should be made in 1 and 2 oz. cases, 6 or 7 inches long, and fired by a leader, brought out of the mouth of the mortar, and turned down the outside, and the end of it covered with paper, to prevent the sparks of the other works from setting it on fire. For a 6 inch mortar, let the quantity of powder for firing be 2 oz. for an 8-inch, $2\frac{3}{4}$ oz. and for a 10 inch, $3\frac{3}{4}$ oz. Care must be taken in these, as well as small mortars, not to put the serpents in too tight, for fear of bursting the mortars. These mortars may be loaded with stars, crackers, &c.

If the mortars, when loaded, are to be sent any distance, or liable to be much moved, the firing powder should be secured from getting amongst the serpents, which would endanger the mortars, as well as hurt their performance; to prevent which, load your mortars thus: first put in the firing powder, and spread it equally about; then cut a round piece of blue touch-paper, equal to the exterior diameter of the mortar, and draw on it a circle, equal to the interior diameter of the mortar, and notch it all round as far as that circle; then paste that part which is notched, and put it down the mortar close to the powder, and stick the pasted edge to the mortar: this will keep the powder always smooth at bottom, so that it may be moved or carried any where, without receiving damage. The large single mortars are called Pots des Aigrettes.

Making, loading, and firing of Pots des Brins.

These are made of paste-board, and must be rolled pretty thick; usually made 3 or 4 inches diameter, and 4 diameters long, and pinched with a neck at one end, like common cases. A number of these are placed on a plank thus: having fixed on a plank 2 rows of wooden pegs, cut, in the bottom of the plank, a groove the whole length under each row of pegs; then, through the centre of each peg, bore a hole down to the groove

at bottom, and on every peg fix and glue a pot, whose mouth must fit tight on the peg: through all the holes run a quick-match, one end of which must go into the pot, and the other into the groove, which must have a match laid in it from end to end, and covered with paper, so that when lighted at one end, it may discharge the whole almost instantaneously: in all the pots put about 1 oz. of meal and corn powder; then in some put stars, and others rains, snakes, serpents, crackers, &c. when they are all loaded, paste paper over their mouths. 2 or 300 of these pots being fired together, make a very pretty show, by affording so great a variety of fires. Fig 32 is a range of pots des brins, with the leader A, by which they are fired.

Pots des Saucissons

Are generally fired out of large mortars without chambers, the same as those for aigrettes, only somewhat stronger: saucissons are made of 1 and 2 oz. cases, 5 or 6 inches long, and choaked in the same manner as serpents: half the number which the mortar contains, must be drove $1\frac{1}{2}$ diameter with composition, and the other half 2 diameters, so that when fired they may give 2 volleys of reports; but if the mortars are very strong, and will bear a sufficient charge, to throw the saucissons very high, you may make 3 volleys of reports, by dividing the number of cases into 3 parts, and making a difference in the height of the charge: after they are filed, pinch and tie them at top of the charge, almost close; only leaving a small vent to communicate the fire to the upper part of the case, which must be filled with corn powder very near the top; then pinch the end quite close, and tie it; after this is done, bind the case very tight with waxed pack-thread, from the choak at top of the composition, to the end of the case; this will make the case very strong in that part, and cause the report to be very loud: saucissons should be rolled a little thicker of paper than the common proportion. When they are to be put in the mortar, they must be primed in their

mouths, and fired by a case of brilliant fire fixed in their centre.

The charge for these mortars should be 1-6th, or 1-8th, more than for pots des aigrettes of the same diameter.

To fix one Rocket on the Top of another.

When sky rockets are thus managed, they are called Towering Rockets, on account of their mounting so very high. Towering rockets are made after this manner; fix on a pound rocket a head without a collar; then take a 4 oz. rocket, which may be headed or bounced, and rub the mouth of it with meal powder wetted with spirit of wine; when done, put it in the head of the large rocket with its mouth downwards; but before you put it in, tick a bit of quick-match in the hole in the clay of the pound rocket, which match should be long enough to go a little way up the bore of the small rocket, to fire it, when the large is burnt out: the 4 oz. rocket being too small to fill the head of the other, roll round it as much tow as will make it stand upright in the centre of the head: the rocket being thus fixed, paste a single paper round the opening of the top of the head of the large rocket. The large rocket must have only half a diameter of charge rammed above the piercer, for, if filled to the usual height, it would turn before the small one takes fire, and entirely destroy the intended effect: when one rocket is headed with another, there will be no occasion for any blowing powder; for the force with which it sets off, will be sufficient to disengage it from the head of the first fired rocket. The sticks for these rockets must be a little longer than for those headed with stars, rains, &c.

Caduceus Rockets,

In rising, form 2 spiral lines, or double worm, by reason of their being placed obliquely, one opposite the other;

other; and their counterpoise in their centre, which causes them to rise in a vertical direction. Rockets for this purpose must have their ends choaked close, without either head or bounce; for a weight at top would be a great obstruction to their mounting; though I have known them sometimes to be bounced, but then they did not rise so high as those that were not; nor do any Caduceus rockets ascend so high as single, because of their serpentine motion, and likewise the resistance of air, which is much greater than 2 rockets of the same size would meet with, if fired singly.

By Fig. 33. you see the method of fixing these rockets: the sticks for this purpose must have all their sides equal, which sides should be equal to the breadth of a stick proper for a sky rocket of the same weight as those you intend to use, and to taper downwards as usual, long enough to balance them, 1 length of a rocket, from the cross stick; which must be placed from the large stick, 6 diameters of 1 of the rockets, and its length 7 diameters; so that each rocket, when tied on, may form with the large stick an angle of 60 degrees. In tying on the rockets, place their heads on the opposite sides of the cross stick, and their ends on the opposite sides of the long stick; then carry a leader from the mouth of one into that of the other. When these rockets are to be fired, suspend them between 2 hooks or nails, then burn the leader through the middle, and both will take fire at the same time. Rockets of 1 lb. are a good size for this use.

Honorary Rockets

Are the same as sky rockets, except that they carry no head nor report, but are closed at top, on which is fixed a cone; then on the case, close to the top of the stick, you tie a 2 oz. case, about 5 or 6 inches long, filled with a strong charge, and pinched close at both ends; then in the reverse sides, at each end, bore a hole in the same manner as in tourbillons; from each hole carry a

leader into the top of the rocket. When the rocket is fired, and arrived to its proper height, it will give fire to the case at top, which will cause both rocket and stick to spin very fast in their return, and represent a worm of fire, descending to the ground.

There is another method of placing the small case, which is by letting the stick rise a little above the top of the rocket, and tying the case to it, so as to rest on the rocket: these rockets have no cones.

There is also a third method, by which they are managed, which is thus: in the top of a rocket fix a piece of wood, in which drive a small iron spindle; then make a hole in the middle of the small case, through which put the spindle; then fix on the top of it a nut, to keep the case from falling off; when this is done, the case will turn very fast, without the rocket: but this method does not answer so well as either of the former.

Fig. 34. is the honorary rocket complete. The best sized rockets for this purpose are those of 1lb.

To divide the Tail of a Sky Rocket so as to form an Arch when ascending.

Having some rockets made, and headed according to fancy, and tied on their sticks; get some sheet tin, and cut it into round pieces about 3 or 4 inches diameter; then on the stick of each rocket, under the mouth of the case, fix 1 of these pieces of tin, 16 inches from the rocket's neck, and support it by a wooden bracket, as strong as possible: the use of this is, that when the rocket is ascending, the fire will play with great force on the tin, which will divide the tail in such a manner, that it will form an arch as it mounts, and will have a very good effect when well managed: if there is a short piece of port-fire, of a strong charge, tied to the end of the stick, it will make a great addition; but this must be lighted before you fire the rocket.

To

To make several Sky Rockets rise in the same direction, and equally distant from each other.

Take 6 or any number of sky rockets, of what size you please; then cut some strong pack-thread into pieces of 3 or 4 yards long, and tie each end of these pieces to a rocket in this manner. Having tied one end of your pack-thread round the body of one rocket, and the other end to another; take a 2nd piece of pack-thread and make one end of it fast to one of the rockets already tied, and the other end to a 3d rocket, so that all the rockets, except the 2 outside, will be fastened to 2 pieces of pack-thread: the length of thread from one rocket to the other, may be what the maker pleases; but the rockets must be all of a size, and their heads filled with the same weight of stars, rains, &c.

Having thus done, fix in the mouth of each rocket a leader of the same length; and, when you are going to fire them, hang them almost close; then tie the ends of the leaders together, and prime them: this prime being fired, all the rockets will mount at the same time, and divide as far as the strings will allow; which division they will keep, provided they are all rammed alike, and well made. They are called, by some, Chained Rockets.

Signal Sky Rockets

Are made of several kinds, according to the different signals intended to be given: but in Artificial Fireworks, 2 sorts are only used, which are one with reports, and the other without; but those for the use of the Navy and Army are headed with stars, serpents, &c. — Rockets which are to be bounced, must have their cases made $1\frac{1}{2}$ or 2 diameters longer than the common proportion, and

and, after they are filled, drive in a double quantity of clay; then bounce and pinch them, after the usual manner, and fix on each a cap.

Signal sky rockets without bounces, are only sky rockets closed and capped: these are very light, therefore do not require such heavy sticks as those with loaded heads; for which reason, you may cut one length of the rocket off the stick, or else make them thinner.

Signal rockets with reports, are fired in small flights; and oft both these, and those without reports, are used for a signal to begin firing a collection of works.

To fix two or more Sky Rockets on one stick.

Two, 3, or 6 sky rockets, fixed on 1 stick, and fired together, make a grand and beautiful appearance; for the tails of all will seem but as one of an immense size, and the breaking of so many heads at once will resemble the bursting of an air ballóon; but the management of this device requires a skilful hand; therefore, for the encouragement of those who are fond of curious performances, I shall give such instructions, that, if well observed, even by those who have not made a great progress in this art, there will be no doubt of the rockets having the desired effect.

Rockets for this purpose must be made with the greatest exactness, all rammed by the same hand, in the same mould, and out of the one proportion of composition; and after they are filled and headed, must all be of the same weight: the stick must also be well made, (and proportioned) to the following directions: first, supposing your rockets to be $\frac{1}{2}$ pounders, whose sticks are 6 feet 6 inches long, then if 2, 3, or 6 of these are to be fixed on 1 stick, let the length of it be 9 feet 9 inches; then cut the top of it into as many sides, as there are rockets, and let the length of each side be equal to the length of 1 of the rockets without its head; and in each side cut a groove, (as usual); then from the grooves
plane

plane it round, down to the bottom, where its thickness must be equal to half the top of the round part. As their thickness cannot be exactly ascertained, I shall give a rule which generally answers for any number of rockets above two: the rule is this; that the stick at top must be thick enough, when the grooves are cut, for all the rockets to lie, without pressing each other, though as near as possible.

When only 2 rockets are to be fixed on 1 stick, let the length of the stick be the last given proportion, but shaped after the common method, and the breadth and thickness, double the dimensions given in the Table, page 50. The point of poise must be in the usual place, (let the number of rockets be what they will :) if sticks made by the above directions should be too heavy, plane them thinner; and if too light, make them thicker; but always make them of the same length.

When more than two rockets are tied on one stick, there will be some danger of their flying up without the stick, unless the following precaution is taken; for cases being placed on all sides, there can be no notches for the cord which ties on the rockets to lie in; therefore, instead of notches, drive a small nail, in each side of the stick, between the necks of the cases; and let the cord, which goes round their necks, be brought close under the nails; by this means the rockets will be as secure, as when tied on singly. Your rockets being thus fixed, carry a quick-match, without a pipe, from the mouth of one rocket to the other; this match being lighted will give fire to all at once.

Though the directions already given may be sufficient for these rockets, I shall here add an improvement of my own, on a very essential part of this device, which is, that of hanging the rockets to be fired; for before I hit upon the following method, many of my essays proved unsuccessful; but to prevent such perplexities, instead of the old and common manner of hanging them on nails or hooks, make use of this contrivance: have a ring made of strong iron wire, large enough

enough for the stick to go in, as far as the mouths of the rockets ; then let this ring be supported by a small iron, at some distance from the post or stand to which it is fixed ; then have another ring, fit to receive and guide the small end of the stick. Rockets thus suspended will have nothing to obstruct their fire ; but when they are hung on nails or hooks, in such a manner, that some of their mouths are against or upon a rail, there can be no certainty of their rising in a vertical direction.

To fire Sky-rockets without Sticks.

You must have a stand, of a block of wood, a foot diameter, and make the bottom flat, so th t it may stand steady ; in the centre of the top of this block draw a circle $2\frac{1}{2}$ inches diameter, and divide the circumference of it into $3 =$ parts ; then take 3 pieces of thick iron wire, each about 3 feet long, and drive them into the block, 1 at each point made on the circle ; when these wires are drove in deep enough to hold them fast, and upright, so that the distance from one to the other is the same at top as at bottom, the stand is complete.

The stand being thus made, prepare your rockets thus : take some common sky-rockets, of any size, and head them as you please ; then get some balls of lead, and tie to each a small wire, 2 or $2\frac{1}{2}$ feet long, and the other end of each wire tie to the neck of a rocket : these balls answer the purpose of sticks, when made of a proper weight, which is about 2-3ds the weight of the rocket ; but when they are of a proper size, they will balance the rocket in the same manner as a stick, at the usual point of poise. To fire these, hang them, one at a time, between the tops of the wires, letting their heads rest on the point of the wires, and the balls hang down between them : if the wires should be too wide for the rockets, press them together, till they fit, and if too close, force them open : the wires for this purpose must be softened, so as not to have any spring,
or

or they will not keep their position, when pressed close or opened.

Rain-falls for Sky-rockets, Double and Single.

Gold and silver rain composition are drove in cases that are pinched quite close at one end: if you roll them dry, 4 or 5 rounds of paper will be strong enough, but if they are pasted, 3 rounds will do; and the thin sort of cartridge paper is best for those small cases, which in rolling you must not turn down the inside edge, as in other cases, for a double edge would be too thick for so small a bore. The moulds for rain-falls should be made of brass, and turned very smooth in the inside; or the cases, which are so very thin, would tear in coming out; for the charge must be drove in tight; and the better the case fits the mould, the more driving it will bear. These moulds have no nipple, but instead of which they are made flat: as it would be very tedious and troublesome to shake the composition out of such small ladles, as are used for these cases, it will be necessary to have a funnel, made of thin tin, to fit on the top of the case, by the help of which you may fill them very fast. For single rain-falls for 4 oz. rockets, let the diameter of the former be 2 16ths of an inch, and the length of the case 2 inches; for 8 oz. rockets, 4 16ths, and 2 diameters of the rocket long; for 1 lb. rockets, 5 16ths, and 2 diameters of the rocket long; for 2 lb. rockets, 5 16ths, and 3 ½ inches long; for 4 lb. rockets, 6 16ths, and 4 ½ inches long; and for 6-pounders, 7 16ths diameter, and 5 inches long.

Of double rain-falls there are 2 sorts; as, for example, some appear first like a star, and then as rain; and some appear first as rain, and then like a star: when you would have stars first, you must fill the cases, within ½ an inch of the top, with rain composition, and the remainder with star composition; but when you intend the rain should be first, drive the case ½ an inch with star composition,
and

the rest with rain. By this method may be made many changes of fire; for in large rockets you may make them first burn as stars, then rain, and again as stars; or they may first shew rain, then stars, and finish with a report; but when they are thus managed, cut open the first-rammed end; after they are filled and bounced, at which place prime them. The star composition for this purpose must be a little stronger than for rolled stars.

Strung Stars.

First take some thin paper, and cut it into pieces of $1\frac{1}{2}$ inch square, or thereabouts; then on each piece lay as much dry star composition as you think the paper will easily contain; then twist up the paper as tight as you can; when done, rub some paste on your hands, and roll the stars between them; then set them to dry: your stars being thus made, get some flax or fine tow, and roll a little of it over each star; then paste your hands and roll the stars as before, and set them again to dry; when they are quite dry, with a piercer make a hole through the middle of each, into which run a cotton quick-match, long enough to hold 10 or 12 stars, at 3 or 4 inches distance: but any number of stars may be strung together by joining the match.

Tailed Stars.

These are called tailed stars, because there are a great number of sparks issue from them, which represent a tail like that of a comet. Of these there are two sorts, which are Rolled and Drove: when rolled, they must be moistened with a liquor made of half a pint of spirit of wine, and half a gill of thin size, of this as much as will wet the composition enough to make it roll easy; when they are rolled, sift meal powder over them, and set them to dry.

When tailed stars are drove, the composition must be moistened with spirit of wine only, and not made so wet

wet as for rolling: 1 and 2 oz. cafes, rolled dry, are best for this purpose; and when they are filled, unroll the case within 3 or 4 rounds of the charge, and all that you unroll cut off; then paste down the loose edge: 2 or 3 days after the cafes are filled, cut them in pieces 5 or 6 8ths of an inch in length; then melt some wax, and dip one end of each piece into it, so as to cover the composition: the other end must be rubbed with meal powder wetted with spirit of wine.

Drove Stars.

Cafes for drove stars are rolled with paste, but are made very thin of paper: before you begin to fill them, damp the composition with spirit of wine that has had some camphor dissolved in it; you may ram them indifferently hard, so that you do not break, or sack the case, to prevent which, they should fit tight in the mould: they are drove in cafes of several sizes, from 8 drams to 4 oz. when they are filled in $\frac{1}{2}$ oz. cafes, cut them in pieces of $\frac{3}{4}$ of an inch long; if 1 oz. cafes, cut them in pieces of 1 inch; if 2 oz. cafes, cut them in pieces of $1\frac{1}{4}$ inch long; and if 4 oz. cafes, cut them in pieces of $1\frac{1}{2}$ inch long: having cut your stars of a proper size, prime both ends with wet meal powder. These stars are seldom put in rockets, they being chiefly intended for air ballóons, and drove in cafes, to prevent the composition from being broke by the force of the blowing powder in the shell.

Rolled Stars

Are commonly made about the size of a musket ball, though they are rolled of several sizes, from the bigness of a pistol ball, to 1 inch diameter; and sometimes very small, but then called Sparks. Great care must be taken in making stars, first, that the several ingredients are reduced to a fine powder; secondly, that the composition is well worked and mixed. Before you begin to roll, take about a pound of composition, and wet it with the following

following liquid, enough to make it stick together and roll easy; spirit of wine 1 quart, in which dissolve $\frac{1}{4}$ of an ounce of isinglass. If a great quantity of composition be wetted at once, the spirit will evaporate, and leave it dry, before you can roll it into stars: having rolled up one proportion, shake the stars in meal powder, and set them to dry, which they will do in 3 or 4 days; but if you should want them for immediate use, dry them in an earthen pan over a slow heat, or in an oven. It being very difficult to make the stars all of an equal size, when the composition is taken up promiscuously with the fingers; therefore I shall here set down a method by which you may make them very exact, which is,—When the mixture is moistened properly, roll it on a flat smooth stone, and cut it into square pieces, making each square large enough for the stars you intend. There is another method used by some to make stars, which is by rolling the composition in long pieces, and then cutting off the star, so that each star will be of a cylindrical form; but this method is not so good as the former, for to make the composition roll this way, it must be made very wet, which makes the stars heavy, as well as weakens them. All stars must be kept as much from air as possible, otherwise they will grow weak and bad.

Scrolls for Sky Rockets.

Cases for scrolls should be made 4 or 5 inches in length, and their interior diameter $\frac{3}{8}$ ths of an inch: one end of these cases must be pinched quite close, before you begin to fill, and when filled, close the other end; then in the opposite sides make a small hole at each end, to the composition, in the same manner as in Tourbillons; and prime them with wet meal powder. You may put in the head of a rocket as many of these cases as it will contain: being fired they turn very quick in the air, and form a scroll or spiral line. They are generally filled with a strong charge, as that of serpents, or brilliant fire.

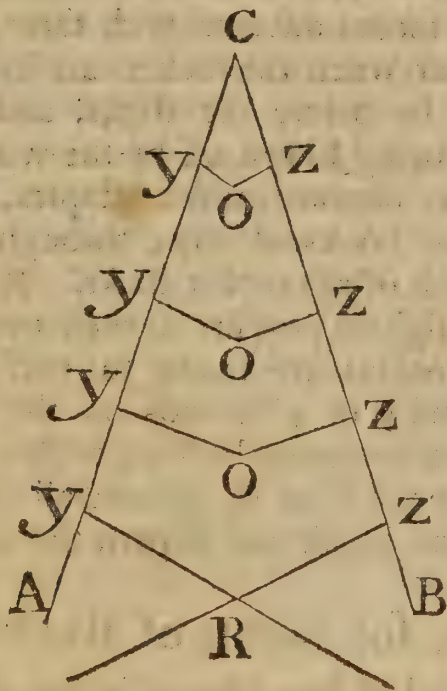
Swarmers,

Swarmers, or small Rockets.

Rockets that go under the denomination of Swarmers, are those from 2 oz. downwards. These rockets are fired sometimes in flights, and in large water-works, &c. Swarmers of 1 and 2 oz. are bored, and made in the same manner as large rockets, except, when headed, their heads must be put on without a collar: the number of strokes for driving 1 oz. must be eight; and for 2 oz. twelve.

All rockets under 1 oz. are not bored, but must be filled to the usual height with composition, which is generally composed of fine meal powder 4 oz. and charcoal or steel dust 2 drams: the number of strokes for ramming these small swarmers is not material, so as they are rammed true, and moderately hard. The necks of unbored rockets must be in the same proportion as in common cases.

The cause of Sky Rockets rising.



Having promised, in the second section, to prove that the effect of sky rockets, and proportion of their charge, depends on the size of the cavity in the composition; I shall here endeavour to give a mathematical demonstration thereof.

Let

Let ABC be the hollow cone for the fire, AYCZB, the superficies of that cone, all the lines OZ at right angles with BC, all the lines OY at right angles with AC: now all the angles ZOY being towards R, whether the angles ZOY are obtuse or acute, but the more acute the better. The rays of fire ZO and YO issuing from the sides of the cone BC and AC, and continually acting with the greater force one upon another at O, forcing the whole BCA upward from the point R; and the wider the cone is, (so as not to exceed one third at bottom, and one sixth at top, of the exterior diameter of the rocket) the greater velocity will the rocket rise with.

Stands for Sky Rockets.

Care must be taken, in placing the rockets, when they are to be fired, to give them a vertical direction at their first setting out; which may be managed thus. Have 2 rails of wood, of any length, supported at each end by a perpendicular leg, so that the rails be horizontal, and let the distance from one to the other be almost equal to the length of the sticks of the rockets intended to be fired; then in the front of the top rail drive square hooks at 8 inches distance, with their points turning sideways, so that when the rockets are hung on them, the points will be before the sticks, and keep them from falling, or being blown off by the wind: in the front of the rail at bottom must be staples, drove perpendicular under the hooks at top; through these staples put the small ends of the rocket sticks. Rockets are fired by applying a lighted port fire to their mouths.

N. B. When sky rockets are made to perfection, and fired, they will stand 2 or 3 seconds on the hook before they rise, and then mount up briskly, with a steady motion, carrying a large tail from the ground all the way up, and, just as they turn, break and disperse the stars.

Girandole Chests, for flights of Rockets,

Are generally composed of four sides, of equal dimensions; but may be made of any diameter, according to the

the number of rockets designed to be fired; its height must be in proportion to the rockets, but must always be a little higher than the rockets with their sticks. When the sides are joined, fix in the top, as far down the chest as the length of one of the rockets with its cap on. In this top, make as many square or round holes to receive the rocket sticks, as you intend to have rockets; but let the distance between them be sufficient for the rockets to stand without touching one another; then from one hole to another cut a groove, large enough for a quick-match to lie in: the top being thus fixed, put in the bottom, at about $1\frac{1}{2}$ foot distance from the bottom of the chest; in this bottom must be as many holes as in the top, and all to correspond; but these holes need not be so large as those in the top.

To prepare your chest, you must lay a quick-match, in all the grooves, from hole to hole; then take some sky rockets, and rub them in the mouth with wet meal powder, and put a bit of match up the cavity of each, which match must be long enough to hang a little below the mouth of the rocket. Your rockets and chest being prepared according to the above directions, put the sticks of the rockets through the holes in the top and bottom of the chest, so that their mouths may rest on the quick-match in the grooves; by which all the rockets will be fired at once; for by giving fire to any part of the match, it will communicate to all the rockets in an instant. As it would be rather troublesome to direct the sticks from the top to the proper holes in the bottom, it will be necessary to have a small door in one of the sides, which when opened, you may see how to place the sticks. Flights of rockets, being seldom fired at the beginning of any fireworks, for which reason they are in danger of being fired by the sparks from wheels, &c. therefore to preserve them, a cover should be made to fit on the chest, and the door in the side kept shut.

Serpents or Snakes for Pots of Aigrettes, Small Mortars, Sky Rockets, &c.

Serpents for this use are made from $2\frac{1}{2}$ inches, to 7 inches long, and their formers from $3\frac{1}{16}$ ths to $5\frac{8}{16}$ ths of an inch diameter; but the diameter of the cases must always be equal to 2 diameters of the former; they are rolled and choaked like other cases, and filled with composition from $5\frac{8}{16}$ ths of an inch, to $1\frac{1}{2}$ inch high, according to the size of the mortars, or rockets, they are designed for, and the remainder of the cases bounced with corn-powder, and afterwards their ends pinched and tied close: before they are used, their mouths must be primed with wet meal-powder.

Leaders, or Pipes of Communication.

The best paper for leaders, is Elephant, which you cut into long slips, 2 or 3 inches broad, so that they may go 3 or 4 times round the former, but not more: when they are very thick, they are too strong for the paper which fastens them to the works, and will sometimes fly off without leading the fire. The formers for these leaders are made from 2 to 6 $\frac{1}{16}$ ths of an inch diameter; but $4\frac{1}{16}$ ths is the size generally made use of: the formers are made of smooth brass wire: when you use them, rub them over with grease, or keep them wet with paste, to prevent their sticking to the paper, which must be pasted all over. In rolling of pipes, make use of a rolling-board, but use it lightly: having rolled a pipe, draw out the former with one hand, holding the pipe as light as possible with the other; for, if it press against the former, it will stick and tear the paper.

N. B. Make your leaders of different lengths, or in clothing of works you will cut a great many to waste. Leaders for marron batteries must be made of strong cartridge paper.

SECT. V. Aquatic Fireworks.

WORKS that sport in the water are much esteemed by most admirers of fireworks, particularly water rockets; but, as they seem of a very extraordinary nature to those who are acquainted with this art, I shall endeavour to explain the method of making them, in as full and easy a manner as possible, as well as other devices for the water.

Water Rockets

May be made from 4 oz. to 2 lb. but, if larger, are too heavy; so that it will be difficult to make them keep above water without a cork float, which must be tied to the neck of the case; but the rockets will not dive so well with, as without floats.

Cases for these are made in the same manner and proportion as sky rockets, only a little thicker of paper. When you fill them which are drove solid, put in first 1 ladle-full of slow fire, then 2 of the proper charge, and on that 1 or 2 ladles of sinking charge, then the proper charge, then the sinking charge again, and so on, till you have filled the case within 3 diameters; then drive on the composition 1 ladle-full of clay; through which make a small hole to the charge; then fill the case, within $\frac{1}{2}$ a diameter, with corn powder, on which turn down 2 or 3 rounds of the case in the inside; then pinch and tie the end very tight: having filled your rockets, (according to the above directions) dip their ends in melted rosin, or sealing wax, or else secure them well with grease. When you fire these rockets, throw in 6 or 8 at a time; but, if you would have them all sink, or swim, at the same time, you must drive them with an equal quantity of composition, and fire them all together.

To make Pipes of Communication, which may be used under Water.

Pipes for this purpose must be a little thicker of paper than those for land. Having rolled a sufficient number of pipes, and kept them till dry, wash them over with drying oil, and set them to dry; but when you oil them, leave about $1\frac{1}{2}$ inch at each end dry, for joints: if they were oiled all over, when you come to join them, the paste would not stick where the paper is greasy: after the leaders are joined, and the paste dry, oil the joints. These pipes will lie many hours under water, without receiving any damage.

Horizontal Wheels for the Water.

First get a large wooden bowl without a handle; then have an octagon wheel made of a flat board, 18 inches diameter, so that the length of each side will be near 7 inches: in all the sides cut a groove for the cases to lie in. This wheel being made, nail it on the top of the bowl; then take 8 four-ounce cases, filled with a proper charge, each about 6 inches in length. Now, to clothe the wheel with these cases, get some whitish-brown paper, and cut it into slips 4 or 5 inches broad, and 7 or 8 long: these slips being pasted all over on one side, take 1 of the cases, and roll 1 of the slips of paper about $1\frac{1}{2}$ inch on its end, so that there will remain about $2\frac{1}{2}$ inches of the paper hollow from the end of the case: this case tie on 1 of the sides of the wheel, near the corners of which must be holes bored, through which you put the pack-thread to tie the cases: having tied on the first case at the neck and end, put a little meal powder in the hollow paper; then paste a slip of paper on the end of another case, the head of which put into the hollow paper on the first, allowing a sufficient distance, from the tail of one to the head of the other, for the pasted paper to bend without tearing: the second case tie on as you did the first;

first; and so on with the rest, except the last, which must be closed at the end, unless it is to communicate to any thing on top of the wheel; such as fire-pumps or brilliant fires, fixed in holes, cut in the wheel, and fired by the last or second case, as the fancy directs: 6, 8, or any number, may be placed on the top of the wheel, so that they are not too heavy for the bowl.

Before you tie on the cases, cut the upper part of all their ends, except the last, a little shelving, that the fire from one may play over the other, without being obstructed by the case. Wheel cases have no clay drove in their ends, nor pinched, but are always left open, only the last, or those which are not to lead fire, which must be well secured.

Water Mines.

For these mines you must have a bowl, with a wheel on it, made in the same manner as the water wheel, only in its middle must be a hole, of the same diameter you design to have the mine. These mines are tin pots, with strong bottoms, and a little more than 2 diameters in length: your mine must be fixed in the hole in the wheel, with its bottom resting on the bowl; then loaded with serpents, crackers, stars, small water rockets, &c. in the same manner as pots of aigrettes; but in their centre fix a case of Chinese fire, or a small gerbe, which must be lighted at the beginning of the last case on the wheel. These wheels are to be clothed as usual.

Fire Globes for the Water.

Bowls for water globes must be very large, and the wheels on them of a decagon form; on each side of which nail a piece of wood 4 inches long, and on the outside of each piece cut a groove, wide enough to receive about $\frac{1}{4}$ of the thickness of a 4 oz. case: these pieces of wood must be nailed in the middle of each face of the wheel, and fixed in an oblique direction, so that the fire from the cases may incline upwards: the wheel

being thus prepared, tie in each groove a 4 oz. case, filled with a grey charge; then carry a leader from the tail of one case to the mouth of the other.

Globes for these wheels are made of 2 tin hoops, with their edges outwards, fixed one within the other, at right angles. The diameter of these hoops must be somewhat less than that of the wheel. Having made a globe, drive in the centre of a wheel an iron spindle, which must stand perpendicular, and its length 4 or 6 inches more than the diameter of the globe.

This spindle serves for an axis, on which the globe is fixed, which, when done, must stand 4 or 6 inches from the wheel: round one side of each hoop must be soldered little bits of tin, $2\frac{1}{2}$ inches distance from each other; which pieces must be 2 inches in length each, and only fastened at one end, the other ends being left loose, to turn round the small port fires, and hold them on: these port fires must be made of such a length, as will last out the cases on the wheel. You are to observe, that there need not be any port fires at the bottom of the globe within 4 inches of the spindle; for, if there were, they would have no effect, but only burn the wheel: all the port fires must be placed perpendicular from the centre of the globe, with their mouths outwards; and must all be clothed with leaders, so as all to take fire with the second case of the wheel; which cases must burn 2 at a time, 1 opposite the other. When 2 cases of a wheel begin together, 2 will end together; therefore the 2 opposite end cases must have their ends pinched and secured from fire. The method of firing such wheels is, by carrying a leader from the mouth of one of the first cases, to that of the other, which leader being burnt through the middle, will give fire to both at the same time.

Odoriferous Water Ballóons.

These ballóons are made in the same manner, as air ballóons, but very thin of paper, and in diameter $1\frac{3}{4}$ inch with a vent of $\frac{1}{2}$ an inch diameter. The shells being made,

made, and quite dry, fill them with any of the following compositions, which must be rammed in tight: these ballóons must be fired at the vent, and put into a bowl of water. Odoriferous works are generally fired in rooms.

Composition I.

Saltpetre 2 oz. flower of sulphur 1 oz. camphor $\frac{1}{2}$ oz. yellow amber $\frac{1}{2}$ oz. charcoal dust $\frac{3}{4}$ oz. flower of benjamin, or assa odorata, $\frac{1}{2}$ oz. all powdered very fine, and well mixed.

Composition II.

Saltpetre 12 oz. meal powder 3 oz. frankincense 1 oz. myrrh $\frac{1}{2}$ oz. camphor $\frac{1}{2}$ oz. charcoal 3 oz. all moistened with the oil of spike.

Composition III.

Saltpetre 2 oz. sulphur $\frac{1}{2}$ oz. antimony $\frac{1}{2}$ oz. amber $\frac{1}{2}$ oz. cedar raspings $\frac{1}{4}$ oz. all mixed with the oil of roses, and a few drops of bergamot.

Composition IV.

Saltpetre 4 oz. sulphur 1 oz. saw-dust of juniper $\frac{1}{2}$ oz. saw-dust of cypress 1 oz. camphor $\frac{1}{4}$ oz. myrrh 2 drams, dried rosemary $\frac{1}{4}$ oz. cortex elaterii $\frac{1}{2}$ oz. all moistened a little with the oil of roses

N. B. Water rockets may be made with any of the above compositions, with a little alteration, to make them weaker or stronger, according to the size of the cases.

Water Ballóons.

Having made some thin paper shells, of what diameter you please, fill some with the composition for water ballóons, and some after this manner. Having made

the vent of the shells pretty large, fill them almost full with water rockets, marrons, squibs, &c. Then put in some blowing powder, sufficient to burst the shells, and afterwards fix in the vent a water rocket, long enough to reach the bottom of the shell, and its neck to project a little out of the vent; this rocket must be open at the end, to fire the powder in the shell, which will burst the shell, and disperse the small rockets, &c. in the water. When you have well secured the large rocket in the vent of the shell, take a cork float with a hole in its middle, which fit over the head of the rocket, and fasten it to the shell: this float must be large enough to keep the ballóon above water.

Water Squibs

Are generally made of 1 oz. serpent cases, 7 or 8 inches long, filled 2 3ds with charge, and the remainder bounced. The common method of firing them is, — Take a water wheel, with a tin mortar in its centre, which load with squibs, after the usual method; but the powder in the mortar must be no more than will just throw the squibs out (easily into the water); you may place the cases on the wheel, either obliquely, or horizontally; and on the top of the wheel, round the mortar, fix six cases of brilliant fire, perpendicular to the wheel: these cases must be fired at the beginning of the last case of the wheel, and the mortar, at the conclusion of the same.

A Sea Fight with small Ships, and to prepare a Fire-ship for it.

Having procured 4 or 5 small ships, of 2 or 3 feet in length, (or as many as you design to fight) make a number of small reports, which are to serve for guns. Of these range as many as you please, on each side of the upper decks; then at the head and stern of each ship fix a 2 oz. case, 8 inches long, filled with a slow port-fire receipt; but take care to place it in such a manner, that

that the fire may fall in the water, and not burn the rigging: in these cases bore holes at unequal distances from one another, but make as many in each case, as half the number of reports, so that one case may fire the guns on one side, and the other those on the opposite. The method of firing the guns, is, by carrying a leader, from the holes in the cases, to the reports on the decks; you must make these leaders very small, and be careful in calculating the burning of the slow fire, in the regulating cases, that more than 2 guns be not fired at a time. When you would have a broadside given, let a leader be carried to a cracker, placed on the outside of the ship, which cracker must be tied loose, or the reports will be too slow; in all the ships put artificial guns at the port holes.

Having filled, and bored holes, in two port fires, for regulating the guns in one ship, make all the rest exactly the same; then when you begin the engagement, light one ship first, and set it a sailing, and so on with the rest, sending them out singly, which will make them fire regularly, at different times, without confusion; for the time between the firing of each gun will be equal to that of lighting the slow fires.

The fire ship may be of any size, and need not be very good, for it is always lost in the action. To prepare a ship for this purpose, make a port fire equal in size with them in the other ships, and place it at the stern; in every port place a large port fire, filled with a very strong composition, and painted in imitation of a gun, and let them all be fired at once by a leader from the slow fire, within 2 or 3 diameters of its bottom; all along both sides, on the top of the upper deck, lay star composition about $\frac{1}{2}$ an inch thick, and 1 broad, which must be wetted with thin size, then primed with meal powder, and secured from fire by pasting paper over it; in the place where you lay this composition, drive some little tacks with flat heads, to hold it fast to the deck: this must be fired just after the sham guns, and when burning will shew a flame all round the ship; at the head take up the decks, and put in a tin mortar loaded with

with crackers, which mortar must be fired by a pipe from the end of the slow fire; the firing of this mortar will sink the ship, and make a pretty conclusion. The regulating port fire of this ship must be lighted at the same time with the first fighting ship.

Having prepared all the ships for fighting, we shall next proceed with the management of them, when on the water. At one end of the pond, just under the surface of the water, fix 2 running blocks, at what distance you chuse the ships should fight; and at the other end of the pond, opposite to each of these blocks, under the water, fix a double block; then on the land, by each of the double blocks, place two small windlasses; round one of them turn one end of a small cord, and the other end put through one of the blocks; then carry it through the single one, at the opposite end of the pond, and bring it back through the double block again, and round the other windlass: to this cord, near the double block, tie as many small strings, as half the number of the ships, at what distance you think proper; but these strings must not be more than 2 feet each: the loose end of each make fast to a ship, just under her bow-sprit; but if tied to the keel, or too near the water, it will overset the ship. Half the ships being thus prepared, near the other double block fix two more windlasses, to which fasten a cord, and to it tie the other half of the ships, as before: when you fire the ships, pull in the cord, with one of the windlasses, to get all the ships together; and when you have set fire to the first, turn that windlass, which draws them out, and so on with the rest, till they are all out, in the middle of the pond; then by turning the other windlass, you will draw them back again; by which method you may make them change sides, and tack about, backwards and forwards, at pleasure. For the fire-ship, fix the blocks and windlasses between the others, so that when she sails out, she will be between the other ships: you must not let this ship advance, till the guns at her ports take fire.

To fire Sky Rockets under Water,

You must have stands made as usual, only the rails must be placed flat, instead of edgeways, and have holes in them for the rocket sticks to go through; for if they were hung upon hooks, the motion of the water would throw them off: the stands being made, if the pond is deep enough, sink them at the sides, so deep, that when the rockets are in, their heads may just appear above the surface of the water; to the mouth of each rocket fix a leader, which put through the hole with the stick; then a little above the water must be a board, supported by the stand, and placed along 1 side of the rockets; then the ends of the leaders are turned up through holes made in this board, exactly opposite the rockets. By this means you may fire them singly, or all at once. Rockets may be fired by this method, in the middle of a pond, by a Neptune, a swan, a water wheel, or any thing else you chuse.

To represent Neptune in his Chariot.

To do this to perfection, you must have a Neptune made (of wood, or basket work) as big as life, fixed on a float, large enough to bear his weight; on which must be 2 horses heads, and necks, so as to seem swimming, as shown by Fig. 35. For the wheels of the chariot, there must be 2 vertical wheels of black fire, and on Neptune's head a horizontal wheel, of brilliant fire, with all its cases, to play upwards. When this wheel is made, cover it with paper, or pasteboard, cut and painted like Neptune's coronet; then let the trident be made without prongs, but instead of them, fix 3 cases of a weak grey charge, and on each horse's head put an 8 oz. case of brilliant fire, and on the mouth of each fix a short case, of the same diameter, filled with the white flame receipt, enough to last out all the cases on the wheels: these short cases must be open at bottom, that they may light the brilliant fires; for the horses eyes put small port fires, and in each

each nostril put a small case filled half with grey charge, and the rest with port-fire composition.

If Neptune is to give fire to any building on the water; at his first setting out, the wheels of the chariot, and that on his head, with the white flames on the horses heads, and the port fires in their eyes and nostrils, must all be lighted at once; then from the bottom of the white flames carry a leader to the trident. As Neptune is to advance by the help of a block and cord, you must manage it so as not to let him turn about, till the brilliant fires on the horses, and the trident, begin; for it is by the fire from the horses, (which plays almost upright) that the building, or work, is lighted; which must be thus prepared. From the mouth of the case, which is to be first fired, hang some loose quick-match, to receive the fire from the horses. When Neptune is only to be shewn by himself, without setting fire to any other works; let the white flames on the horses be very short, and not to last longer than one case of each wheel, and let 2 cases of each wheel burn at a time.

Swans and Ducks in Water.

If you would have the swans, or ducks, discharge rockets into the water, they must be made hollow, and of paper, and filled with small water rockets, with some blowing powder, to throw them out; but if this is not done, they may be made of wood, which will last many times. Having made and painted some swans, fix them on floats; then in the places where their eyes should be, bore holes two inches deep, inclining downwards, and wide enough to receive a small port fire; the port fire cases for this purpose must be made of brass, 2 inches long, and filled with a slow bright charge; in the middle of one of these cases make a little hole, then put the port fire in the eye hole of the swan, leaving about half an inch to project out, and in the other eye put another port fire, with a hole made in it; then in the neck of the swan, within two inches of one of the eyes, bore

bore a hole slantways, to meet that in the port fire; in this hole put a leader, and carry it to a water rocket, that must be fixed under the tail with its mouth upwards; on the top of the head place 2 one-ounce cases, 4 inches long each, drove with brilliant fire; one of these cases must incline forwards, and the other backwards; these must be lighted at the same time as the water rocket; to do which, bore a hole between them, in the top of the swan's head, down to the hole in the port fire, to which carry a leader; if the swan is filled with rockets, they must be fired by a pipe, from the end of the water rocket under the tail. When you set the swan a swimming, light the 2 eyes.

Water Fire-Fountains.

To make a fire fountain, you must first have a float made of wood, 3 feet diameter, then in the middle fix a round perpendicular post, 4 feet high, and 2 inches diameter; round this post fix 3 circular wheels, made of thin wood, without any spokes. The largest of these wheels must be placed within 2 or 3 inches of the float, and must be nearly of the same diameter. The 2d wheel must be 2 feet 2 inches diameter, and fixed at 2 feet distance from the first. The 3d wheel must be 1 foot 4 inches diameter, and fixed within 6 inches of the top of the post: the wheels being fixed, take 18 four or 8 ounce cases, of brilliant fire, and place them round the first wheel, with their mouths outwards, and inclining downwards; on the 2d wheel place 13 cases of the same, and in the same manner, as those on the first; on the 3d place 8 more of these cases, in the same manner as before, and on the top of the post fix a gerbe; then clothe all the cases with leaders, so that both they and the gerbe may take fire at the same time. Before you fire this work, try it in the water, to see if the float is properly made, so as to keep the fountain upright.

SECT. VI.—Crackers.

CUT some cartridge paper into pieces $3\frac{1}{2}$ inches broad, and 1 foot long; 1 edge of each fold down lengthwise about $\frac{3}{4}$ of an inch broad; then fold the double edge down $\frac{1}{4}$ of an inch, and turn the single edge back half over the double fold; then open it, and lay all along the channel, which is formed by the folding of the paper, some meal powder; then fold it over and over, till all the paper is doubled up, rubbing it down every turn; this done, bend it backwards and forwards, $2\frac{1}{2}$ inches, or thereabouts, at a time as oft as the paper will allow; then hold all these folds flat and close, and with a small pinching cord give one turn round the middle of the cracker, and pinch it close; then bind it with pack-thread, as tight as you can; then in the place where it was pinched, prime one end of it, and cap it with touch-paper. When these crackers are fired, they will give a report at every turn of the paper: if you would have a great number of bounces, you must cut the paper longer, or join them after they are made; but if they are made very long before they are pinched, you must have a piece of wood with a groove in it, deep enough to let in half the cracker: this will hold it straight, while it is pinching. Fig. 36. represents a cracker complete.

Single Reports.

Cases for reports are generally rolled on 1 and 2 oz. formers, and seldom made larger, but on particular occasions; they are made from 2 to 4 inches long, and very thick of paper: having rolled a case, pinch one end quite close, and drive it down; then fill the case with corn powder, only leaving room to pinch it at top; but before you pinch it, put in a piece of paper at top of the powder.

powder. Reports are fired by a vent, bored in the middle, or at one end, just as required.

Marrons.

Formers for marrons are from $\frac{3}{4}$ of an inch, to $1\frac{1}{2}$ diameter. Cut the paper for the cases twice the diameter of the former broad, and long enough to go 3 times round; when you have rolled a case, paste down the edge, and tie one end close; then with the former drive it down to take away the wrinkles, and make it flat at bottom; then fill the case with corn powder 1 diameter and $\frac{1}{4}$ high, and fold down the rest of the case tight on the powder. The marron being thus made, wax some strong pack-thread with shoemakers wax; this thread wind up in a ball, then unwind 2 or 3 yards of it, and that part which is near the ball, make fast to a hook; then take a marron, and stand as far from the hook as the pack-thread will reach, and wind it lengthwise round the marron as close as you can, till it will hold no more that way; then turn it and wind the pack-thread on the short way, then lengthwise again, and so on till the paper is all covered; then make fast the end of the pack-thread, and beat down both ends of the marron, to bring it in shape. The method of firing marrons, is by making a hole at one end with an awl, and putting in a piece of quick-match; then take a piece of strong paper, in which wrap up the marron, with 2 leaders, which must be put down to the vent, and the paper tied tight round them with small twine; these leaders are bent on each side, and their loose ends tied to other marrons, and are nailed in the middle to the rail of the stand, as in Fig. 37. The use of winding the pack-thread in a ball is, that you may let it out as you want it, according to the quantity the marron may require; and that it may not be tied in knots, which would spoil the marron.

Marron Batteries,

If well managed, will keep time to a march, or a slow piece of music. Marron batteries are made of several stands, with a number of cross rails, for the marrons, which are regulated by leaders, by cutting them of different lengths, and nailing them tight, or loose according to the time of the music. In marron batteries you must use the large and small marrons, and the nails for the pipes must have flat heads.

Line Rockets

Are made and drove as the sky rockets, but have no heads; and the cases must be cut close to the clay; they are sometimes made with 6 or 7 changes, but in general not more than 4 or 5: the method of managing those rockets is,—First, have a piece of light wood, the length of 1 of the rockets, turned round about $2\frac{1}{2}$ inches diameter, with a hole through the middle lengthwise, large enough for the line to go easily through: if you design 4 changes, have 4 grooves cut in the swivel, one opposite the other, to lay the rockets in.

The mouths of the rockets being rubbed with wet meal powder, lay them in the grooves, head to tail, and tie them fast; from the tail of the first rocket carry a leader to the mouth of the second, and from the second to the third, and so on to as many as there are on the swivel, making every leader very secure; but in fixing these pipes, take care that the quick-match does not enter the bores of the rockets: the rockets being fixed on the swivel, and ready to be fired, have a line 100 yards long, stretched and fixed up tight, at any height from the ground; but be sure to place it horizontal: this length of line will do for $\frac{1}{2}$ lb. rockets; but, if larger, the line must be longer: before you put up the line, put one end of it through the swivel, and when you fire the line rocket, let the mouth of that rocket which you fire first, face that end of the line where you stand; then the first
rocket

rocket will carry the rest to the other end of the line, and the second will bring them back, and so they will run out and in according to the number of rockets: at each end of the line, there must be a piece of flat wood, for the rocket to strike against, or its force will cut the line. Let the line be well soaped, and the hole in the swivel very smooth.

Different Decorations for Line Rockets.

To line rockets may be fixed great variety, such as flying dragons, mercuries, ships, &c. Or they may be made to run on the line like a wheel, which is done in this manner. Have a flat swivel, made very exact, and on it tie two rockets obliquely, one on each side, which will make it turn round all the way it goes, and form a circle of fire; the charge for these rockets should be a little weaker than common; if you would shew 2 dragons fighting, get 2 swivels made square, and on each tie 3 rockets together, on the under side; then have 2 flying dragons made of tin, and fix one of them on the top of each swivel, so as to stand upright; in the mouth of each dragon put a small case of common fire, and another at the end of the tail; you may put 2 or 3 port fires, of a strong charge, on 1 side of their bodies, to shew them. This done, put them on the line, one at each end; but let there be a swivel in the middle of the line, to keep the dragons from striking together: before you fire the rockets light the cases on the dragons, and if care be taken in firing both at the same time, they will meet in the middle of the line, and seem to fight. Then they will run back, and return with great violence; which will have a very pleasing effect. The line for these rockets must be very long, or they will strike too hard together.

Chinese Flyers.

Cases for flyers may be made of different sizes, from 1 to 8 ounces: they must be made thick of paper, and 3 interior diameters long; they are rolled in the same
H manner

manner as tourbillons, with a straight pasted edge, and pinched close at one end. The method of filling them is, the case being put in a mould, whose cylinder, or foot, must be flat at top without a nipple, fill it within $\frac{1}{2}$ a diameter of the middle; then ram in $\frac{1}{2}$ a diameter of clay, on that as much composition as before, on which drive $\frac{1}{2}$ a diameter of clay; then pinch the case close, and drive it down flat; after this is done, bore a hole exactly through the centre of the clay in the middle; then in the opposite sides at both ends make a vent, and in that side you intend to fire first make a small hole to the composition near the clay in the middle, from which carry a quick match, covered with a single paper, to the vent at the other end; then when the charge is burnt on one side, it will, by means of the quick match, communicate to the charge in the other, (which may be of a different sort). The flyers being thus made, put an iron pin, that must be fixed in the work on which they are to be fired, and on which they are to run: through the hole in the middle, on the end of this pin, must be a nut to keep the flyer from running off. If you would have them turn back again after they are burnt, make both the vents at the ends on the same side, which will alter its course the contrary way.

Table Rockets

Are designed merely to shew the truth of driving, and the judgement of a fire worker, they having no other effect, when fired, than spinning round, in the same place where they begin, till they are burnt out, and shewing nothing more than an horizontal circle of fire.

The method of making these rockets is— Have a cone turned out of hard wood, 2 $\frac{1}{2}$ inches diameter, and as much high; round the base of it draw a line; on this line fix 4 spokes, 2 inches long each, so as to stand one opposite the other; then fill 4 nine-inch 1lb. cases, with any strong composition, within 2 inches of the top: these cases are made like tourbillons, and must be rammed with the greatest exactness.

Your rockets being filled, fix their open ends on the short spokes; then in the side of each case bore a hole

hole near the clay; all these holes, or vents, must be so made that the fire of each case may act the same way; from these vents carry leaders to the top of the cone, and tie them together. When you would fire the rockets, set them on a smooth table, and light the leaders in the middle, and all the cases will fire together (see Fig. 38.) and spin on the point of the cone.

These rockets may be made to rise like tourbillons, by making the cases shorter, and boring 4 holes in the under side of each at equal distances: this being done, they are called Double Tourbillons.

Note, all the vents in the under side of the cases must be lighted at once; and the sharp point of the cone cut off, at which place make it spherical.

To make Wheels and other Works incombustible.

It being necessary, when your works are new, to paint them of some dark colour; therefore, if instead of which, you make use of the following composition, it will give them a good colour, and in a great measure prevent their taking fire so soon as if painted. Take brick dust, coal ashes, and iron filings, of each an equal quantity, and mix them with a double size, made hot. With this wash over your works, and when dry wash them over again; this will preserve the wood greatly against fire. Let the brick-dust and ashes be beat to a fine powder.

Single Vertical Wheels.

There are different sorts of vertical wheels, some having their fells of a circular form, others of an hexagon, octagon, or decagon form, or any number of sides, according to the length of the cases you design for the wheel: your spokes being fixed in the nave, nail slips of tin, with their edges turned up, so as to form grooves for the cases to lie in, from the end of one spoke to another; then tie your cases in the grooves, head to tail, in the

same manner as those on the horizontal water wheel, so that the cases successively taking fire from one another, will keep the wheel in an equal rotation. Two of these wheels are very oft fired together, one on each side of a building, and both lighted at the same time, and all the cases filled alike, to make them keep time together, which they will do if made by the following directions. In all the cases of both wheels, except the first, on each wheel, drive 2. or 3 ladles full of slow fire, in any part of the cases; but be careful to ram the same quantity in each case, and in the end of one of the cases, on each wheel, you may ram 1 ladle full of dead fire composition, which must be very lightly drove; you may also make many changes of fire, by this method.

Let the hole in the nave of the wheel be lined with brass, and made to turn on a smooth iron spindle. On the end of this spindle let there be a nut, to screw off and on; when you have put the wheel on the spindle, screw on the nut, which will keep the wheel from flying off. Let the mouth of the first case be a little raised. See fig. 39. Vertical wheels are made from 10 inches to 3 feet diameter, and the size of the cases must differ accordingly; 4 oz. cases will do for wheels of 14 or 16 inches diameter, which is the proportion generally used. The best wood for wheels of all sorts, is a light and dry beech.

Horizontal Wheels

Are best when their fells are made circular; in the middle of the top of the nave must be a pintle, turned out of the same piece as the nave, 2 inches long, and equal in diameter to the bore of 1 of the cases of the wheel: there must be a hole bored up the centre of the nave, within $\frac{1}{2}$ an inch of the top of the pintle. The wheel being made, nail at the end of each spoke (of which there should be 6 or 8) a piece of wood, with a groove cut in it to receive the case. These pieces fix in such a manner, that half the cases may incline upwards, and
half

half downwards, and that when they are tied on, their heads and tails may come very near together: from the tail of one case to the mouth of the other carry a leader, which secure with pasted paper. Besides these pipes, it will be necessary to put a little meal powder inside the pasted paper, to blow off the pipe, that there may be no obstruction to the fire, from the cases. By means of these pipes, the cases will successively take, burning one upwards, and the other downwards. On the pintle fix a case of the same sort as those on the wheel; this case must be fired by a leader, from the mouth of the last case on the wheel, which case must play downwards: instead of a common case in the middle, you may put a case of Chinese fire, long enough to burn as long as 2 or 3 of the cases on the wheel.

Horizontal wheels are oft fired 2 at a time, and made to keep time, like vertical wheels; only they are made without any slow or dead fire; 10 or 12 inches will be enough for the diameter of wheels with 6 spokes. Fig. 40. represents a wheel on fire, with the first case burning.

Spirali Wheels

Are only double horizontal wheels, and made thus: The nave must be about 6 inches long, and somewhat thicker than the single sort; instead of the pintle at top, make a hole for the case to be fixed in; and 2 sets of spokes, one set near the top of the nave, and the other near the bottom. At the end of each spoke cut a groove, wherein you tie the cases, there being no fell; the spokes should not be more than $3\frac{1}{2}$ inches long each from the nave, so that the wheel may not be more than 8 or 9 inches diameter; the cases are placed in such a manner, that those at top play down, and those at bottom play up, but let the 3d or 4th case play horizontally. The case in the middle may begin with any of the others, you please: 6 spokes will be enough for each set, so that the wheel may consist of 12 cases, besides that on the top: the cases 6 inches each.

Plural Wheels

Are made to turn horizontally, and to consist of 3 sets of spokes, placed 6 at top, 6 at bottom, and 4 in the middle, which must be a little shorter than the rest: let the diameter of the wheel be 10 inches; the cases must be tied on the ends of the spokes, in grooves cut on purpose, or in pieces of wood nailed on the ends of the spokes, with grooves cut in them as usual: in clothing these wheels, make the upper set of cases play obliquely downwards, and them at bottom obliquely upwards, and them in the middle horizontally. In placing the leaders, you must order it so that the cases may burn thus, viz. first up, then down, then horizontal, and so on with the rest; but another change may be made, by driving in the end of the eighth case, 2 or 3 ladders full of slow fire, to burn till the wheel has stopped its course; then let the other cases be fixed the contrary way, which will make the wheel run back again: for the case at top you may put a small gerbe; and let the cases on the spokes be short, and filled with a strong brilliant charge.

Illuminated Spiral Wheel.

First have a circular horizontal wheel, made 2 feet diameter, with a hole quite through the nave; then take 3 thin pieces of deal, 3 feet long each, and $\frac{3}{4}$ of an inch broad each: one end of each of these pieces nail to the fell of the wheel, at an equal distance from one another, and the other end nail to a block with a hole in its bottom, which must be perpendicular with that in the block of the wheel, but not so large. The wheel being thus made, have a hoop planed down very thin and flat; then nail one end of it to the fell of the wheel, and wind it round the 3 sticks in a spiral line, from the wheel to the block at top: on the top of this block fix a case of Chinese fire; on the wheel you may place any number of cases, which must incline downwards, and burn 2 at a time. If the wheel should consist of 10 cases, you may let the illuminations
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and Chinese fire begin with the second cases. The spindle for this wheel must be a little longer than the cone, and made very smooth at top, on which the upper block is to turn, and the whole weight of the wheel to rest. See Fig. 41.

Double Spiral Wheel.

For this wheel the block, or nave, must be as long as the height of the worms, or spiral lines, but must be made very thin, and as light as possible. In this block must be fixed several spokes, which must diminish in length, from the wheel to the top, so as not to exceed the surface of a cone of the same height. To the ends of these spokes nail the worms, which must cross each other several times: these worms clothe with illuminations, the same as those on the single wheels; but the horizontal wheel you may clothe as you like. At top of the worm place a case of spur-fire, or an amber light. See Fig. 42. This figure is shewn without leaders, to prevent a confusion of lines.

Ballóon Wheels

Are made to turn horizontally: they must be made 2 feet diameter, without any spokes, and very strong, with any number of sides. On the top of a wheel range and fix tin pots, 3 inches diameter, and 7 inches high each, as many of these as there are cases on the wheel: near the bottom of each pot make a small vent; into each of these vents carry a leader from the tail of each case; some of the pots load with stars, and some with serpents, crackers, &c. As the wheels turn, the pots will successively be fired, and throw into the air a great variety of fires.

Fruiloni Wheels.

First have a nave made 9 inches long, and 3 in diameter: near the bottom of this nave fix 8 spokes, with a

H 4

hole

hole in the end of each, large enough to receive a 2 or 4 ounce case: each of these spokes may be 14 inches long from the block. Near the top of this block fix 8 more of the same spokes, exactly over the others, but not so long by 2 inches. As this wheel is to run horizontally, all the cases in the spokes at top must play obliquely upwards, and all them in the spokes at bottom obliquely downwards. This being done, have a small horizontal wheel made with 8 spokes, each 5 inches long from the block: on the top of this wheel place a case of brilliant fire: all the cases on this wheel must play in an oblique direction downwards, and burn 2 at a time, and those on the large wheel 4 at a time; that is, 2 of those in the top set of spokes, and 2 of them in the bottom set of spokes.

The 4 first cases on the large wheel, and the 2 first on the small, must be fired at the same time, and the brilliant fire at top, at the beginning of the last cases. The cases of the wheels may be filled with a grey charge. When these wheels are completed, you must have a strong iron spindle, made 4 feet 6 long, and fixed perpendicular on the top of a stand: on this put the large wheel, whose nave must have a hole quite through from the bottom to the top. This hole must be large enough to turn easy round the bottom of the spindle, at which place there must be a shoulder, to keep the wheel from touching the stand: at the top of the spindle put the small wheel, and join it to a large one with a leader, in order to fire them both together.

Port-Fires for Illuminations

Have their cases made very thin of paper, and rolled on formers, from 2 to 5 8ths of an inch diameter, and are made from 2 to 6 inches long: they are pinched close at one end, and left open at the other: when you fill them, put in but a little composition at a time, and ram it in lightly, so as not to break the case: 3 or 4 rounds of paper, with the last round pasted, will be strong enough for these cases.

Common

Common Port-Fires

Are intended purposely to fire the works, their fire being very slow, and the heat of the flame so intense, that, if applied to rockets, leaders, &c. it will fire them immediately. Port fires may be made of any length, but are seldom made more than 21 inches long: the interior diameter of port-fire moulds should be 10 16ths of an inch, and the diameter of the former, $\frac{1}{2}$ an inch. The cases must be rolled wet with paste, and one end pinched, or folded down. The moulds should be made of brass, and to take in 2 pieces lengthwise; then, when the case is in the 2 sides, they are held together by brass rings, or hoops, which are made to fit over the outside. The bore of the mould must not be made quite through, so that there will be no occasion for a foot. Those port fires, when used, are held in copper sockets, fixed on the end of a long stick: these sockets are made like port crayons, only with a screw, instead of a ring.

Cascades of Fire

Are made of any size; but one made according to the dimensions of that shewn in Plate 4. Fig. 43. will be large enough for 8 oz cases. Let the distance from A to B, be 3 feet; from B to C, 2 feet 6 inches; and from C D, 2 feet; and let the cross piece at A, be 4 feet long; then from each end of this piece, draw a line to D; then make the other cross pieces so long as to come within those lines. The top piece D, may be of any length so as to hold the cases, at a little distance from each other; all the cross pieces are fixed horizontally, and supported by brackets; the bottom cross piece should be about 1 foot 6 inches broad in the middle, the second 1 foot, the third 9 inches, and the top piece 4 inches: the cases may be made of any length, but must be filled with a brilliant charge. On the edges of the cross pieces must be nailed bits of wood, with a groove cut in each piece, large enough

enough for a case to lie in. These bits of wood are fixed so as to incline downwards, and that the fire from one tier of cases may play over the other. All the cases being tied fast on, carry leaders from one to the other, and let there be a pipe hang from the mouth of one of the cases, covered at the end with a single paper, which you burn to fire the cascade.

The Fire-Tree.

To make a fire-tree, as shewn by Fig. 44. you must first have a piece of wood 6 feet long, and 4 inches square; then at E, 9 inches from the top, make a hole in the front, and in each side; or, instead of holes, you may fix short pegs, to fit the inside of the cases. At F 9 inches from E, fix 3 more pegs; at G, 1 foot 9 inches from F, fix 3 pegs; at H, 9 inches from G, fix 3 pegs; at I, 9 inches from H, fix 3 pegs, inclining downwards; but all the other pegs must incline upwards, that the cases may have the same inclination as you see in the figure: then at top place a 4-inch mortar, loaded with stars, rains, or crackers. In the middle of this mortar place a case filled with any sort of charge, but let it be fired with the other cases: a brilliant charge will do for all the cases; but the mortar may be made of any diameter, and the tree of any size; and on it any number of cases, provided they are placed in the manner described.

Chinese Fountains.

To make a Chinese fountain, you must have a perpendicular piece of wood, 7 feet long, and $2\frac{1}{2}$ inches square. 16 inches from the top, fix on the front a cross piece 1 inch thick, and $2\frac{1}{2}$ broad, with the broad side up: below this, fix 3 more pieces, of the same width and thickness, at 16 inches from each other: let the bottom rail be 5 feet long, and the others of such a length as to allow the fire pumps to stand in the middle of the intervals of each other. The pyramid being thus made, fix in the holes made in the bottom rail, 5 fire pumps, at equal

equal distances : on the 2d rail place 4 pumps ; on the 3d, 3 ; on the 4th, 2 ; and on the top of the post, 1 : but place them all to incline a little forwards, that, when they throw out the flars, they may not strike against the cross rails. Having fixed your fire pumps, clothe them with leaders, so that they may all be fired together. See Fig. 45.

Of Illuminated Globes with Horizontal Wheels.

The hoops for these globes may be made of wood, tin, or iron wire, about 2 feet diameter. For a single globe take 2 hoops, and tie them together, one within the other, at right angles ; then have a horizontal wheel made, whose diameter must be a little wider than the globe, and its nave 6 inches long, on the top of which the globe is fixed, so as to stand 3 or 4 inches from the wheel : on this wheel you may put any number of cases, filled with what charge you like ; but let 2 of them burn at a time : they may be placed horizontally, or to incline downwards, just as you chuse. Now, when the wheel is clothed, fix on the hoops as many illuminations as will stand within $2\frac{1}{2}$ inches of each other : these you fasten on the hoops with small iron binding wire ; and when they are all on, put on your pipes of communication, which must be so managed, as to light them all with the 2d or 3d case on the wheel. The spindle on which the globe is to run must go through the block of the wheel, up to the inside of the top of the globe, where must be fixed a bit of brass, or iron, with a hole in it to receive the point of the spindle, on which the whole weight of the wheel is to bear, as in Fig. 46. which represents a globe on its spindle. By this method may be made a crown, which is done by having the hoops bent in the form of a crown. Sometimes globes and crowns are ordered so as to stand still, and the wheel only to turn round ; but when you would have the globe or crown to stand still, and the wheel
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to run by itself, the block of the wheel must not be so long, nor the spindle any longer than to just raise the globe a little above the wheel; and the wheel cases and illumination must begin together.

Dodecaedron.

So called because it nearly represents a twelve-sided figure, and is made thus. First have a ball turned out of some hard wood, 14 inches diameter: when done, divide its surface into 14 equal parts, from which bore holes $1\frac{1}{2}$ inch diameter, perpendicular to the centre, so that they may all meet in the middle: then let there be turned in the inside of each hole a female screw; and to all the holes, but one, must be made a round spoke. 5 feet long, with 4 inches of the screw at one end, to fit the holes; then in the screw end of all the spokes bore a hole, 5 inches up, which must be bored flanting, so as to come out at one side, a little above the screw; from which cut a small groove along the spoke, within 6 inches of the other end, where you make another hole through to the other side of the spoke: in this end fix a spindle, on which put a small wheel, of 3 or 4 sides, each side 6 or 7 inches long: these sides must have grooves cut in them, large enough to receive a 2 or 4 oz. case: when these wheels are clothed, put them on the spindles, and at the end of each spindle put a nut to keep the wheel from falling off: the wheels being thus fixed, carry a pipe from the mouth of the first case on each wheel, thro' the hole in the side of the spoke, and from thence along the groove, and through the other hole, so as to hang out at the screw end about an inch. The spokes being all prepared in this manner, you must have a post, on which you intend to fire the work, with an iron screw in the top of it, to fit one of the holes in the ball: on this screw fix the ball; then in the top hole of the ball put a little meal powder, and some loose quick-match; then screw in all the spokes, and in one side of the ball bore a hole, in which put a leader, and secure it at the end; and your work will be ready to be fired. By this leader the powder

der and match in the centre is fired, which will light the match at the ends of the spokes all at once, whereby all the wheels will be lighted at once. There may be an addition to this piece, by fixing a small globe on each wheel, or 1 on the top wheel only. A grey charge will be proper for the wheel cases.

The Yew Tree of Brilliant Fire

Is represented by Fig. 47. as it appears when burning. First, let A be an upright piece of wood, 4 feet long, 2 inches broad, and 1 thick: at top of this piece, on the flat side, fix a hoop, 14 inches diameter; and round its edge and front place illuminations; and in the centre a 5-pointed star; then at E, which is $1\frac{1}{2}$ foot from the edge of the hoop, place 2 cases of brilliant fire, 1 on each side: these cases should be 1 foot long each: below these fix 2 more cases of the same size, and at such a distance, that their mouths may almost meet them at top: then, close to the ends of these cases, fix 2 more of the same cases; they must stand parallel to them at E. The cases being thus fixed, clothe them with leaders; so that they, with the illuminations and star at top, may all take fire together.

Stars with Points for Regulated Pieces, &c.

These stars are made of different sizes, according to the work for which they are intended: they are made with cases from 1 oz. to 1 lb. but in general with 4 oz. cases, 4 or 5 inches long: the cases must be rolled with paste, and twice as thick of paper as a rocket of the same bore. Having rolled a case, pinch one end of it quite close; then drive in $\frac{1}{2}$ a diameter of clay, and when the case is dry, fill it with composition, 2 or 3 inches, to the length of the cases, with which it is to burn: at top of the charge drive some clay; as the ends of these cases are seldom punched, they would be liable to take fire. Having filled a case, divide the circumference of it at the pinched end close to the clay into 5 equal parts; then bore

bore 5 holes with a gimblet, about the size of the neck of a common 4 oz. case, into the composition: from one hole to the other carry a quick-match, and secure it with paper: this paper must be put on in the manner of that on the ends of wheel cases, so that the hollow part, which projects from the end of the case, may serve to receive a leader from any other work, to give fire to the points of the star. These stars may be made with any number of points.

Fixed Sun with a Transparent Face.

To make a sun of the best sort there should be 2 rows of cases, as in Fig. 48, which will shew a double glory, and make the rays strong and full. The frame, or sun wheel, must be made thus: Have a circular flat nave made very strong, 12 inches diameter: to this fix 6 strong flat spokes, A, B, C, D, E, F. On the front of these fix a circular fell, 5 feet diameter; within which fix another fell, the length of one of the sun cases less in diameter; within this fix a 3d fell, whose diameter must be less than the 2d, by the length of 1 case and 1 3d. The wheel being made, divide the fells into so many equal parts as you would have cases (which may be done from 24 to 44): at each division fix a flat iron staple: these staples must be made to fit the cases, to hold them fast on the wheel: let the staples be so placed, that one row of cases may lie in the middle of the intervals of the other.

In the centre of the block of the sun drive a spindle, on which put a small hexagon wheel, whose cases must be filled with the same charge as the cases of the sun: 2 cases of this wheel must burn at a time, and begin with them on the fells. Having fixed on all the cases, carry pipes of communication from one to the other, as you see in the figure, and from one side of the sun to the wheel in the middle, and from thence to the other side of the sun. These leaders will hold the wheel steady while the sun is fixing up, and will also
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be a sure method of lighting both cases of the wheel together. A fun thus made is called a Brilliant fun, because the wood work is intirely covered with fire from the wheel in the middle, so that there appears nothing but sparks of brilliant fire: but, if you would have a Transparent face in the centre, you must have one made of pasteboard, of any size. The method of making a face is, by cutting out the eyes, nose, and mouth, for the sparks of the wheel to appear through; but, instead of this face, you may have one painted on oiled paper, or Persian silk, strained tight on a hoop; which hoop must be supported by 3 or 4 pieces of wire, at 6 inches distance from the wheel in the centre, so that the light of it may illuminate the face. By this method you may have, in the front of a fun, *VIVAT REX*, cut in pasteboard, or Apollo painted on silk; but, for a small collection, a fun with a single glory, and a wheel in front, will be most suitable. $\frac{1}{2}$ lb. cases, filled 10 inches with composition, will be a good size for a fun of 5 feet diameter; but, if larger, the cases must be greater in proportion.

Three Vertical Wheels illuminated, which turn on their own Naves upon a Horizontal Table.

A plan of this is shewn by Fig. 49. Let D be a deal table 3 feet 6 diameter: this table must be fixed horizontally on the top of a post; on this post must be a perpendicular iron spindle, which must come through the centre of the table: then let A, B, C, be 3 spokes joined to a triangular flat piece of wood, in the middle of which make a hole to fit easily over the spindle: let E, F, G, be pieces of wood, 4 or 5 inches long each, and 2 inches square, fixed on the under sides of the spokes; in these pieces make holes lengthwise to receive the thin part of the blocks of the wheels, which, when in, are prevented from coming out by a small iron pin being run through the end of each. K, L, M, are 3 vertical octagon wheels,

wheels, 18 inches diameter each: the blocks of these wheels must be long enough for 3 or 4 inches to rest on the table; round which part drive a number of sharp points of wire, which must not project out of the blocks more than $\frac{1}{16}$ th of an inch: the use of these points is, that, when the blocks run round, they will stick in the table, and help the wheels forward: if the naves are made of strong wood, one inch will be enough for the diameter of the thin part, which should be made to turn easy in the holes in the pieces E, F, G. On the front of the wheels make 4 or 5 circles of strong wire, or flat hoops, and tie on them as many illuminations as they will hold at 2 inches from each other: instead of circles, you may make spiral lines, clothed with illuminations, at the same distance from each other as those on the hoops. When illuminations are fixed on a spiral line in the front of a wheel, they must be placed a little on the flant, the contrary way that the wheel runs: the cases for these wheels may be filled with any coloured charge, but must burn only one at a time.

The wheels being thus prepared, you must have a globe, crown, or spiral wheel, to put on the spindle in the middle of the table: this spindle should be just long enough to raise the wheel of the globe, crown, or spiral wheel, so high that its fire may play over the 3 vertical wheels: by this means their fires will not be confused, nor will the wheels receive any damage from the fire of each other. In clothing this work, let the leaders be so managed, that all the wheels may light together, and the illuminations after 2 cases of each wheel are burnt.

Illuminated Chandelier.

Illuminated works are much admired by the Italians, and indeed are a great addition to a collection of works: in a grand exhibition an illuminated piece should be fired after every 2 or 3 wheels, or fixed pieces of common and brilliant fires; and likewise illuminated works may be made cheap, quick, and easy.

To make an illuminated chandelier, you must first have one made of thin wood. See Fig. 50. The chandelier being made, bore in the front of the branches, and in the body, and also in the crown at top, as many holes for illuminations as they will contain, at 3 inches distance from each other: in these holes put illuminations filled with white, blue, or brilliant charge. Having fixed in the port fires, clothe them with leaders, so that the chandelier and crown may light together. The small circles on this figure represent the mouths of the illuminations, which must project strait from the front.

Illuminated Yew-Tree.

First have a tree made of wood, such as is shewn by Fig. 51. The middle piece, or stem, on which the branches are fixed, must be 8 feet 6 inches high: at the bottom of this piece draw a line, at right angles, 2 feet 6 inches long at each side; then from L. which is 1 foot 6 inches from the bottom, draw a line on each side to C and D: these lines will give the length of the 2 first branches. Then put on the 2 top branches parallel to them at bottom: let the length of each of these branches be 1 foot from the stem: from the ends of these 2 branches draw a line to C and D: then fix on 5 more branches at an = distance from each other, and their length will be determined by the lines A C and E D. When the branches are fixed, place illuminating port fires on the top of each, as many as you chuse: behind the top of the stem fasten a gerbe, or white fountain, which must be fired at the beginning of the illuminations on the tree.

Flaming Stars with Brilliant Wheels.

To make a flaming star, you must first have made a circular piece of strong wood about 1 inch thick and 2 feet diameter: round this block fix 8 points, 2 feet 6 inches long each; 4 of these points must be straight, and 4 flaming: these points being joined on very strong, and even
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with the surface of the block, nail tin or pasteboard on their edges, from the block to the end of each, where they must be joined: this tin must project in front 8 inches, and be joined where they meet at the block; round the front of the block fix 4 pieces of thick iron wire, 8 inches long each, equally distant from each other: this being done, cut a piece of pasteboard round, 2 feet diameter, and draw on it a star, as may be seen in Fig. 52. This star cut out, and on the back of it paste oiled paper; then paint each point half red, and half yellow, lengthwise; but the body of the star must be left open, wherein must run a brilliant wheel, made thus: Have a light block turned 9 inches long; at each end of it fix 6 spokes; at the end of each spoke put a 2 oz. case of brilliant fire: the length of these cases must be in proportion to the wheel, and the diameter of the wheel when the cases are on must be a little less than the diameter of the body of the small star: the cases on the spokes in front must have their mouths incline outwards, and them on the inside spokes must be placed so as to form a vertical circle of fire. When you place your leaders, carry the first pipe from the tail of 1 of the cases in front to the mouth of 1 of the inside cases, and from the tail of that to another in front, and so on to all the cases. Your wheel being made, put it on a spindle, in the centre of the star; this spindle must have a shoulder at bottom, to keep the wheel at a little distance from the block. This wheel must be kept on the spindle by a nut at the end; having fixed on the wheel, fasten the transparent star to the 4 pieces of wire: when you fire it, you will only see a common horizontal wheel; but when the first case is burnt out, it will fire one of the vertical cases, which will shew the transparent star, and fill the large flames and points with fire; then it will again appear like a common wheel, and so on for 12 changes.

Touch

Touch-Paper for Capping of Serpents, Crackers, &c.

Dissolve, in spirits of wine or vinegar, a little saltpetre; then take some purple or blue paper, and wet it with this liquor, and when dry it will be fit for use; when you paste this paper on any of your works, take care that the paste does not touch that part which is to burn. The method of using this paper is by cutting it into slips, long enough to go once round the mouth of a serpent, cracker, &c. When you paste on these slips, leave a little above the mouth of the case not pasted; then prime the case with meal powder, and twist the paper to a point.

Projected Regulated Piece of Nine Mutations.

A regulated piece, if well executed, is as curious a work as any in fireworks: it consists of fixed and moveable pieces on one spindle, representing various figures, which take fire successively one from another, without any assistance after lighting the first mutation; but, for the better explanation of this piece, I shall give a full description of the method of communicating the fire from one mutation to the other, with a figure of each as they stand on the spindle. Regulated pieces are made of many kinds, and of any number of mutations, from 2 to 9, which is the greatest number I ever knew a piece to consist of, except one of my own making, which was composed of 15 mutations, all different fires and figures: but, as an explanation of so large a piece would be difficult to comprehend, I shall omit it, leaving so many changes to those who have made a great progress in this art, and only teach the manner of making a piece of 9 mutations, as shewn in Plate V, Fig. 53. As it will be necessary that every mutation should be separately explained,

I shall first give the name of each, with the colour of fire, and size of the case belonging to it; after which proceed with the proportion of each mutation, with the nature of the spindle, and placing the leaders.

First Mutation

Is a hexagon vertical wheel, illuminated in front with small port fires tied on the spokes; this wheel must be clothed with 2 oz. cases, filled with black charge; the length of these cases is determined by the size of the wheel, but must burn singly.

Second Mutation

Is a fixed piece, called a Golden Glory, by reason of the cases being filled with spur-fire; the cases must stand perpendicular to the block on which they are fixed, so that, when burning, they may represent a glory of fire: this mutation is generally composed of 5 or 7 2-oz. cases.

Third Mutation

Is moveable, and is only an octagon vertical wheel, clothed with 4 oz. cases, filled with brilliant charge; 2 of these cases must burn at a time: in this wheel you may make changes of fire.

Fourth Mutation

Is a fixed fun of brilliant fire, consisting of 12 4-oz. cases; the necks of these cases must be a little larger than those of 4 oz. wheel cases: in this mutation may be made a change of fire, by filling the cases half with brilliant charge, and half with grey.

Fifth Mutation

Is a fixed piece, called the Porcupine's Quills; this piece consists of 12 spokes, standing perpendicular to the

the block in which they are fixed; on each of these spokes, near the end, must be placed a 4 oz. case of brilliant fire; all these cases must incline either to the right or left, so that they may all play one way.

Sixth Mutation

Is a standing piece, called the Cross Fire. This mutation consists of 8 spokes fixed in a block; near the end of each of those spokes must be tied 2 4-oz. cases of white charge, one across the other, so that the fires from the cases on 1 spoke may intersect the fire from cases on the other.

Seventh Mutation

Is a fixed wheel, with 2 circular fells, on which are placed 16 8-ounce cases of brilliant fire, in the form of a star: this piece is called a Fixed Star of Wild-fire.

Eighth Mutation.

This is a beautiful piece, called a Brilliant Star-piece: it consists of 6 spokes, which are strengthened by 2 fells of a hexagon form, at some distance from each other; at the end of each spoke, in the front is fixed a brilliant star of 5 points; and on each side of every star is placed a 4 oz. case of black or grey charge; these cases must be placed with their mouths sideways, so that their fires may cross each other.

Ninth Mutation

Is a wheel piece: this is composed of 6 long spokes, with a hexagon vertical wheel at the end of each; these wheels run on spindles in the front of the spokes; all the wheels are lighted together: 2 oz. cases will do for these wheels, and may be filled with any coloured charge.

After having spoke of the several parts of the regulated piece, each by their proper names and colour of fire, I shall next proceed with the proportion of every mutation, with the method of conveying the fire from one to the other, and the distance they stand one from the other on the spindle.

First Mutation

Must be a hexagon vertical wheel, 14 inches diameter; on one side of the block, whose diameter is $2\frac{1}{4}$ inches, is fixed a tin barrel, A, see Fig. 53, No. 1. this barrel must be a little less in diameter than the nave; let the length of the barrel and block be 6 inches. Having fixed the cases on the wheel, carry a leader from the tail of the last case into the tin barrel through a hole made on purpose, 2 inches from the block; at the end of this leader let there be about 1 inch or 2 of loose match; but take care to secure well the hole wherein the pipe is put, to prevent any sparks falling in, which would light the second mutation before its time, and confuse the whole.

Second Mutation

Is thus made. Have a nave turned $2\frac{1}{2}$ inches diameter, and 3 long; then let $\frac{1}{2}$ an inch of that end which faces the first wheel be turned so as to fit easy into the tin barrel of the first mutation, which must turn round it without touching; on the other end of the block fix a tin barrel, B, N^o. 2. this barrel must be 6 inches long, and only $\frac{1}{2}$ an inch of it to fit on the block. Round the nave fix 5 spokes, $1\frac{1}{2}$ inch long each; the diameter of the spokes must be equal to a 2 oz former; on these spokes put 5 7-inch 2-oz. cases of spur fire, and carry leaders from the mouth of one to the other, that they may all light together; then from the mouth of 1 of the cases, carry a leader through a hole bored slantways in the nave, from between the spokes, to the front of the block near the spindle hole; the end of this leader must project out of

of the hole into the barrel of the first mutation, so that when the pipe which comes from the end of the last case on the first wheel flashes, it may take fire, and light the 2d mutation. To communicate the fire to the 3d mutation, bore a hole near the bottom of one of the 5 cases to the composition, and from thence carry a leader into a hole made in the middle of the barrel B: this hole must be covered with pasted paper.

Third Mutation

May be either an octagon or hexagon wheel, 20 inches diameter; let the nave be $3\frac{1}{4}$ inches diameter, and $3\frac{1}{2}$ in length; $1\frac{1}{2}$ inch of the front of the nave must be made to fit in the barrel B. On the other end of the block fix a tin barrel, C, N^o. 3. this barrel must be $6\frac{1}{2}$ inches in length, one inch of which must fit over the block. The cases of this wheel must burn 2 at a time; and from the mouths of the 2 first cases carry a leader, through holes in the nave, into the barrel of the second mutation, after the usual manner; but besides these leaders let there be a pipe go across the wheel from one first case to the other; then from the tail of one of the last cases carry a pipe into a hole in the middle of the barrel C: at the end of this pipe let there hang some loose quick match.

Fourth and Fifth Mutations.

I shall here speak of those 2 mutations under 1 head, as their naves are made of 1 piece, which from E to F is 14 inches; E, a block 4 inches diameter, with 10 or 12 short spokes, on which are fixed 11 inch 8 oz. cases: let the front of this block be made to fit easy in the barrel C, and clothe the cases so that they may all light together; and let a pipe be carried through a hole in the block into the barrel C, in order to receive the fire from the leader brought from the last case on the wheel. G, the nave of the 5th mutation, whose diameter must be $4\frac{1}{2}$ inches: in this nave fix 10 or 12 spokes $1\frac{1}{2}$ foot in length

length each; these spokes must stand 7 inches distant from the spokes of the 4th mutation; and at the end of each spoke tie a 4 oz. case, as N^o. 5. all these cases are to be lighted together, by a leader brought from the end of 1 of the cases on N^o. 4. Let F and H be of the same piece of wood as E and G, but as much thinner as possible, to make the work light.

Sixth and Seventh Mutations.

The blocks of these 2 mutations are turned out of 1 piece of wood, whose length from F to P is 15 inches. L, a block 5 inches diameter, in which are fixed 8 spokes, each 2 foot 4 inches long; at the end of each spoke tie 2 4-oz. cases, as N^o. 6. all these cases must be fired at the same time, by a pipe brought from the end of one of the cases on the 5th mutation. Let the distance between the spokes at L and those in the 5th mutation be 7 inches. M, the nave of the 7th mutation, whose diameter must be $5\frac{1}{2}$ inches: in this nave fix 8 spokes, and on the front of them 2 circular fells, 1 of 4 feet 8 inches diameter, and 1 of 3 feet 11 inches diameter; on these fells tie 16 8-oz. or pound cases as in N^o. 7. and carry leaders from one to the other, so that they may be all fired together. This mutation must be fired by a leader brought from the tail of one of the cases on the sixth mutation.

Eighth and Ninth Mutations.

The blocks of these may be turned out of one piece, whose length from P to D must be 12 inches. O, the block of the 8th mutation, which must be 6 inches diameter, and in it fixed 6 spokes, each 3 feet in length, strengthened by an hexagon fell within 3 or 4 inches of the ends of the spokes; close to the end of each spoke, in the front, fix a five-pointed brilliant star; then 7 inches below each star, tie 2 10-inch 8-oz. cases, so that the upper ends of the cases may rest on the fells, and their ends on the spokes; each of these cases must be placed parallel to the opposite fell. See N^o. 8. NNN, &c. are the cases, and kkk, &c. the stars.

The

The 9th mutation is thus made. Let D be a block 7 inches diameter; in this block must be screwed 6 spokes, 6 feet long each, with holes and grooves for leaders, as those in the dodecaedron; at the end of each spoke, in the front, fix a spindle for a hexagon vertical wheel, 10 inches diameter, as in N^o. 9. When these wheels are on, carry a leader from each into the block, so that they may all meet; then lead a pipe from the end of 1 of the cases of the 8th mutation, through a hole bored in the block D, to meet the leaders from the vertical wheels, so that they may all be fired together.

The spindles for large pieces are required to be made very strong, and as exact as possible; for a piece of 9 mutations, let the spindle be at the large end 1 inch diameter, and continue that thickness as far as the 7th mutation, and from thence to the 5th; let its diameter be $\frac{3}{4}$ of an inch; from the fifth to the fourth, $\frac{5}{8}$ ths of an inch; from the fourth to the second, $\frac{1}{2}$ an inch; and from the second to the end, $\frac{3}{8}$ ths of an inch: at the small end must be a nut to keep on the first wheel, and at the thick end must be a large nut, as shewn by the figure; so that the screw part of the spindle being put through a post, and a nut screwed on tight, the spindle will be held fast and steady; but you are to observe, that that part of the spindle, on which the moveable pieces are to run, be made long enough for the wheels to run easy without sticking; the fixed pieces being made on different blocks, the leaders must be joined, after they are fixed on the spindle. The best method of preventing the fixed mutations from moving on the spindle, is, to make that part of the spindle which goes through them square; but as it would be difficult to make square holes through such long blocks as are sometimes required, it will be best to make them thus; Bore a round hole a little larger than the diameter of the spindle, and at each end of the block over the hole, fasten a piece of brass with a square hole in it to fit the spindle.

To make an Horizontal Wheel change
to a Vertical Wheel with a Sun in
Front.

The sudden change of this piece is very pleasing, and gives great surprize to those who are not acquainted with the contrivance. A wheel for this purpose should be about 3 feet diameter, and its fell circular, on which tie 16 half-pound cafes filled with brilliant charge; 2 of these cafes must burn at a time, and on each end of the nave must be a tin barrel of the same construction as those on the regulated piece; the wheel being completed, prepare the post or stand thus: first have a stand made of any height, about 3 or 4 inches square; then saw off from the top, a piece 2 feet long; this piece join again at the place where it was cut, with a hinge on one side, so that it may lift up and down in the front of the stand, then fix on the top of the bottom part of the stand, on each side a bracket: these brackets must project at right angles with the stand, 1 foot from the front, for the short piece to rest on; but these brackets must be placed a little above the joint of the post, so that when the upper stand falls, it may lie between them at right angles with the bottom stand, which may be done by fixing a piece of wood, 1 foot long, between the brackets, and even with the top of the bottom stand; then, as the brackets rise above the bottom stand, they will form a channel for the short post to lie in, and keep it steady without straining the hinge: on the side of the short post opposite the hinge, nail a piece of wood, of such a length, that, when the post is perpendicular, it may reach about $1\frac{1}{2}$ foot down the long post, to which being tied, it will hold the short stand upright: the stand being thus prepared, in the top of it fix a spindle 10 inches long; on this spindle put the wheel, then fix on a brilliant sun with a single glory; the diameter of this sun must be 6 inches less than that of the wheel. When you fire this piece, light the wheel first, and let it
run

run horizontally till 4 cases are consumed; then from the end of the 4th case carry a leader into the tin barrel that turns over the end of the stand; this leader must be met by another brought through the top of the post, from a case filled with a strong port-fire charge, and tied to the bottom post, with its mouth facing the pack-thread which holds up the stand, so that when this case is lighted, it will burn the pack-thread, and let the wheel fall forward, by which means it will become vertical; then from the last case of the wheel, carry a leader into the barrel next the gun, which will begin as soon as the wheel is burnt out.

Grand Volute illuminated with a projected Wheel in Front.

First have 2 hoops made of strong iron wire, one of 6 feet diameter, and one of 4 feet 2 inches; these hoops must be joined to scrolls A, A, A, &c. as in Fig. 54. These scrolls must be made of the same sort of wire as the hoops: on these scrolls tie, with iron binding wire, as many illuminating port-fires as they will hold, at 2 inches distance: these port fires clothe with leaders, so that they may all take fire together; then let C be a circular wheel of 4 spokes, 3 feet 6 inches diameter, and on its fell tie as many 4 oz. cases, head to tail, as will complete the circle, only allowing a sufficient distance between the cases, that the fire may pass free, which may be done by cutting the upper part of the end of each case a little shelving: on each spoke fix a 4 oz. case about 3 inches from the fell of the wheel; these cases are to burn one at a time, and the first of them to begin with those on the fell, of which 4 are to burn at a time, so that the wheel will last no longer than $\frac{1}{4}$ of the cases on the fell, which in number should be 16 or 20: on the front of the wheel form a spiral line, with strong wire, on which tie port fires, placing them on a slant, with their mouths to face the same way as the cases on the wheel; all these port fires must be fired with the 2d cases of wheel. Let D, D, D, &c. be spokes of wood, all made to screw into a block in the centre; each of these
spokes

spokes may be in length about 4 feet 6 inches; in the top of each fix a spindle, and on each spindle put a spirali wheel of 8 spokes, such as E, E, E, &c. The blocks of these wheels must have a hole at top for the centre cases, and the spindle must have nuts screwed on their ends; which nuts should fit in the holes at top of the blocks, so that all the wheels must be put on before you fix in the centre cases: as some of these wheels by reason of their situation will not bear on the nut, it will be necessary to have smooth shoulders made on the spindles for the blocks to run on; the cases of these wheels are to burn double, and the method of firing them is, by carrying a leader from each down the spokes into the block in the centre, as in the dodecaedron, but the centre case of each wheel must begin with the 2 last cases as usual. It is to be observed, that the large circular wheel in front must have a tin barrel on its block, into which a pipe must be carried from one of the second cases on the wheel; this pipe being met by another from the large block, in which the 8 spokes are screwed, will fire all the spirali wheels and the illuminating port fires at the same time. The cases of the projected wheel may be filled with a white charge, and those of the spirali wheels, with a grey.

Moon and Seven Stars.

Let Fig. 55. be a smooth circular board, 6 feet diameter; out of the middle of it cut a circular piece 12 or 14 inches diameter, and over the vacancy put white Persian silk, on which paint a moon's face; then let I, I, I, &c. be stars each 4 or 5 inches diameter, cut out with 5 points, and covered with oiled silk: on the front of the large circular board, draw a 7-pointed star, as large as the circle will allow; then on the lines which form this star, bore holes, wherein fix pointed stars. When this piece is to be fired, it must be fixed upon the front of a post, on a spindle, with a wheel of brilliant fire behind the face of the moon; so that while the wheel burns, the moon and stars will appear transparent, and when the wheel has burnt out, they will disappear,

appear, and the large star in front, which is formed of pointed stars, will begin, being lighted by a pipe of communication from the last case of the vertical wheel, behind the moon; this pipe must be managed in the same manner as those in regulated pieces.

Double Cone Wheel Illuminated.

This piece is represented by Fig. 56. Let A be a strong decagon wheel, 2 feet 6 inches diameter; then on each side of it fix a cone B and C; these cones are to consist of a number of hoops, supported by 3 or 4 pieces of wood, in the manner of the spiral wheels: let the height of each cone be 3 feet 6 inches, and on all the hoops tie port fires horizontally, with their mouths outwards, and clothe the wheel with 8 ounce cases, all to play horizontally, 2 at a time: the cones may be fired with the first or second cases. The spindle for this piece must go through both the cones, and rise 3 feet above the point of the cone at top, so that its length will be 10 feet 4 inches from the top of the post H, in which it is fixed, allowing 4 inches for the thickness of the block of the wheel: the whole weight of the wheel and cones must bear on a shoulder in the spindle, on which the block of the wheel must turn: near the top of the spindle must be a hole in the front, into which screw a small spindle, after the cones are on; then on this small spindle fix a sun, D, composed of 16 nine-inch 4 oz. cases, of brilliant fire; which cases must not be placed on a fell, but only stuck into a block of 6 inches diameter: then in the front of this sun must be a circular vertical wheel, 16 inches diameter; on the front of this wheel form with iron wire a spiral line, and clothe it with illuminations, after the usual method. As this wheel is not to be fired till the cones are burnt out, the method of firing it is.—Let the hole in the block, at the top of the uppermost cone, be a little larger than the spindle which passes through it; then, from the first case of the vertical wheel before the sun, carry a leader down the side of the spindle to the top
of

of the block of the horizontal wheel, on which must be a tin barrel; then this leader, being met by another brought from the end of the last case of the horizontal wheel, will give fire to the vertical wheel, so soon as the cones are extinguished; but the gun, D, must not be fired, till the vertical wheel is quite burnt out.

Fire-Pumps.

Cases for fire-pumps are made as those for tourbillons; only they are pasted, instead of being rolled dry. Having rolled and dried your cases, fill them: first put in a little meal powder, and then a star; on which ram lightly a ladle or 2 of composition, then a little meal powder, and on that a star, then again composition, and so on till you have filled the case. Stars for fire-pumps should not be round, but must be made either square, or flat and circular, with a hole through the middle: the quantity of powder for throwing the stars must increase as you come near the top of the case; for, if much powder be put at the bottom, it will burst the case. The stars must differ in size, in this manner: let the star which you put in first, be about $\frac{1}{4}$ less than the bore of the case; but let the next star be a little larger, and the 3d star a little larger than the 2d, and so on: let them increase in diameter, till within 2 of the top of the case, which 2 must fit in tight. As the loading of fire-pumps is somewhat difficult, it will be necessary to make 2 or 3 trials, before you depend on their performance: when you fill a number of pumps, take care not to put in each an equal quantity of charge between the stars, so that when they are fired they may not throw up too many stars together. Cases for fire-pumps should be made very strong, and rolled on 4 or 8 oz. formers, 10 or 12 inches long each.

Vertical

Vertical Scroll Wheel.

This wheel may be made of any diameter, but must be constructed as in Fig. 57, to do which proceed thus: Have a block made of a moderate size, into which fix 4 flat spokes, and on them fix a flat circular fell of wood; round the front of this fell place port-fires; then on the front of the spokes form a scroll, either with a hoop or strong iron wire; on this scroll tie cases of brilliant fire, in proportion to the wheel, head to tail, as in the figure. When you fire this wheel, light the first case near the fell; then, as the cases fire successively, you will see the circle of fire gradually diminish; but whether the illuminations on the fell begin with the scroll, or not, is immaterial, that being left intirely to the maker.

N. B. This wheel may be put in the front of a regulated piece, or fired by itself, occasionally.

Pin-Wheels.

First roll some paper pipes, about 14 inches long each: these pipes must not be made thick of paper, 2 or 3 rounds of elephant paper being sufficient. When your pipes are thoroughly dried, you must have made a tin tube, 12 inches long, to fit easy into the pipes; at one end of this tube fix a small conical cup, which done is called a funnel: then bend 1 end of 1 of the pipes, and put the funnel in at the other, as far as it will reach, and fill the cup with composition: then draw out the funnel by a little at a time, shaking it up and down; and it will fill the pipe as it comes out. Having filled some pipes, have made some small blocks, about 1 inch diameter, and $\frac{1}{2}$ inch thick: round 1 of these blocks wind and paste a pipe, and to the end of this pipe join another; which must be done by twisting the end of one pipe to a point, and putting it into the end of the other, with a little paste: in this manner join 4 or 5 pipes, winding them one upon the other, so as to form a spiral line. Having wound on your pipes,
paste

paste 2 slips of paper across them, to hold them together: besides these slips of paper the pipes must be pasted together.

There is another method of making these wheels, called the French; which is, by winding on the pipes without paste, and sticking them together with sealing-wax, at every half-turn; so that, when they are fired, the end will fall loose every time the fire passes the wax; by which means the circle of fire will be considerably increased. The formers for these pipes are made from $1\frac{1}{2}$ to 4 16ths of an inch diameter, and the composition for them as follows; meal powder 8 oz. saltpetre 2 oz. and sulphur 1: among these ingredients may be mixed a little steel-filings, or the dust of cast iron: this composition should be very dry, and not made too fine, or it will stick in the funnel. These wheels may be fired on a large pin, and held in the hand with safety.

Fire-Globes.

There are 2 sorts of fire globes, one with projected cases, the other with the cases concealed thus: Have a globe made of wood, of any diameter you chuse, and divide the surface of it into 14 equal parts, and at each division bore a hole perpendicular to the centre: these holes must be in proportion to the cases intended to be used: in every hole, except one, put a case filled with brilliant, or any other charge, and let the mouths of the cases be even with the surface of the globe; then cut in the globe a groove, from the mouth of one case to the other, for leaders, which must be carried from case to case, so that they may all be fired together: this done, cover the globe with a single paper, and paint it. These globes may be used to ornament a building.

Fire-globes with projected cases are made thus: Your globe being made with 14 holes bored in it as usual, fix in every hole, except one, a case, and let each case project from the globe 2 thirds of its length; then clothe all the cases with leaders, so that they may all take fire at

at the same time. Fire-globes are supported by a pintle, made to fit the hole in which there is no case.

To thread and join Leaders, and place them on different Works.

Joining and placing Leaders is a very essential part of fire-works, as it is on the leaders that the performance of all complex works depends; for which reason I shall endeavour here to explain the method of conducting pipes of communication, in as plain a manner as possible. Your works being ready to be clothed, proceed thus: Cut your pipes of a sufficient length to reach from one case to the other; then put in the quick-match, which must always be made to go in very easy: when the match is in, cut it off within about an inch of the end of the pipe, and let it project as much at the other end; then fasten the pipe to the mouth of each case with a pin, and put the loose ends of the match into the mouths of the cases, with a little meal powder: this done to all the cases, paste over the mouth of each 2 or 3 bits of paper. The preceding method is used for large cases, and the following for small, and for illuminations: First thread a long pipe; then lay it on the tops of the cases, and cut a bit off the under side, over the mouth of each case, so that the match may appear; then pin the pipe to every other case, but before you put on the pipes, put a little meal powder in the mouth of each case: if the cases thus clothed are port fires on illuminated works, cover the mouth of each case with a single paper; but, if they are choaked cases, situated so that a number of sparks from other works may fall on them before they are fired, secure them with 3 or 4 papers, which must be pasted on very smooth, that there may be no creases for the sparks to lodge in, which oft set fire to the works before their time. Avoid, as much as possible, placing the leaders too near, or one across the other so as to touch, as it may happen that the flash of one will fire the other; therefore, if your works should be so formed, that the leaders must cross or touch, be sure

to make them very strong, and secure at the joints, and at every opening.

When a great length of pipe is required, it must be made by joining several pipes in this manner: Having put on 1 length of match as many pipes as it will hold, paste paper over every joint; but, if a still greater length is required, more pipes must be joined, by cutting off about an inch of one side of each pipe near the end, and laying the quick-match together, and tying them fast with small twine; after which, cover the joining with pasted paper.

Placing Fire-works to be exhibited, with the Order of Firing.

Nothing adds more to the appearance of fire-works, than the placing them properly; though the manner of placing them chiefly depends on the judgement of the maker. I shall give such rules here, as have been generally observed; for example, whether your works are to be fired on a building, or on stands: If they are a double set, place one wheel of a sort on each side of the building; and next to each of them, towards the centre, place a fixed piece, then wheels, and so on; leaving a sufficient distance between them, for the fire to play from one without burning the other: Having fixed some of your works thus in front, place the rest behind them, in the centre of their intervals: the largest piece, which is generally a regulated or transparent piece, must be placed in the centre of the building, and behind it a sun, which must always stand above all the other works: a little before the building, or stands, place your large gerbes; and at the back of the works, fix your marron batteries, pots des aigrettes, pots des brins, pots des fauciflons, air ballóons, and flights of rockets: the rocket stands may be fixed behind, or any where else, so as not to be in the way of the works.

Single

Single collections are fired on stands; which stands are made in the same manner as theodolite stands, only the top part must be long or short occasionally: these stands may be fixed up very soon without much trouble. Having given sufficient instructions for placing of fireworks, I shall proceed with the manner of firing them.

Order of Firing.

1. Two signal
2. Six sky
3. Two honorary
4. Four caduceus
5. } {vertical } wheels illuminated
6. } Two { spiral }
7. } {transparent stars }
8. A line rocket of 5 changes
9. Four tourbillons
10. } {horizontal wheels }
11. } {air ballóons illuminated }
12. } Two { Chinese fountains }
13. } {regulating pieces of 4 mutations each }
14. } {pots des aigrettes }
15. Three large gerbes
16. A flight of rockets
17. } Two { ballóon wheels }
18. } {cascades of brilliant fire }
19. Twelve sky rockets
20. } Two { illuminated yew trees }
21. } {air ballóons of serpents, and 2 compound }
22. Four tourbillons
23. } Two { Fruiloni wheels }
24. } {illuminated globes with horizontal wheels }
25. One pot des fauciffons
26. Two plural wheels
27. Marron battery
28. Two chandeliers illuminated
29. Range of pots des brins
30. Twelve

30. Twelve sky rockets
31. Two yew-trees of fire
32. Nest of serpents
33. Two double cones illuminated
34. Regulating piece of seven mutations, viz.
 1. Vertical wheel illuminated
 2. Golden glory
 3. Octagon vertical wheel
 4. Porcupine's quills
 5. Cross fires
 6. Star piece with brilliant rays
 7. Six vertical wheels
35. Brilliant sun
36. Large flight of rockets.

When water-works are to be exhibited, divide them into several sets, and fire one set after every fifth or sixth change of land and air-works. Observe this rule in firing a double set of works; always to begin with sky-rockets, then two moveable pieces; then two fixed pieces, and so on; ending with a large flight of rockets, or a marron battery: if a single collection, fire a fixed piece after every wheel or two, and now and then some air and water-works.

Fountain of Sky Rockets.

Plate 6th, Fig. 1. represents a fountain of 30 rockets. Let A be a perpendicular post, 16 feet high from the ground, and 4 inches square. Let the rail, or cross piece, C, be 1 foot 6 inches long, 3 inches broad, and 1 thick. The rail D, at bottom, must be 6 feet long, 1 foot broad, and 1 inch thick. F, and G, are the two sides which serve to supply the rails D, E, H, I, C: these sides are 1 foot broad at bottom, and cut in the front with a regular slope, to 3 inches at top; but their back edges must be parallel with the front of the pots A. The breadth of the rails E, H, I, will be determined by the breadth of the sides: all the rails must be fixed at 2 feet distance

distance from each other, and at right angles with the pots. Having placed the rails thus, bore in the bottom rail 10 holes, at equal distances, large enough to receive the stick of a one-pound rocket; in the back edge of this rail cut a groove from one end to the other, fit to contain a quick-match; then cut a groove in the top of the rail, from the edge of each hole, into the groove in the back: in the same manner cut in the second rail, E, 8 holes and grooves; in the third rail, H, 6 holes and grooves; in the fourth rail, I, 4 holes and grooves; and in the top rail, 2 holes and grooves. B, a rail with holes in it to guide the ends of the rocket sticks: this rail must be fixed 6 feet from the rail D. The fountain frame being thus made, prepare your rockets thus: Tie round the mouth of each a piece of thin paper, large enough to go twice round, and to project about an inch and $\frac{1}{2}$ from the mouth of the rocket, which must be rubbed with wet meal-powder; in the mouth of each rocket put a leader, which secure well with the paper that projects from the mouth of the case: these leaders must be carried into the grooves in the back of the rails, in which lay a quick-match from one end to the other, and cover it with pasted paper: holes must be made in the rail D, to receive the ends of the sticks of the rockets, in the rail E, and so on to the fourth rail; so that the sticks of the rockets at top will go through all the rails. The rockets being so prepared, fix a gerbe, or white flower pot, on each rail, before the post, with their mouths inclining a little forwards: these gerbes must be lighted all at once. Behind or before each gerbe, fix a case of brilliant or flow fire: these cases must be filled so that they may burn out one after the other, to regulate the fountain, which may be done by carrying a leader, from the end of each flow or brilliant fire, into the groove in the back of each rail. Different sized rockets may be used in these fountains; but it will be best to fill the heads of the rockets on each rail with different sorts of things, in this manner; those at top with crackers, the next with rains, the third with

serpents, the fourth with tailed stars, and the last flight with common or brilliant stars.

Palm-Tree.

This piece, though made of common fires, and of a simple construction, has a very pleasing effect; owing to the fires intersecting so oft, that they resemble the branches of trees. Fig. 2d. Let *A* be a perpendicular post, of any thickness, so that it is sufficiently strong to hold the cases: let the distance from *B* to *C* be 2 feet 6 inches, and from *C* to *D* 2 feet 6 inches; and let the length of each cross piece be 2 feet; on each end of each fix a five-pointed star; then fix on pegs made on purpose, 12 inch half-pound cases of brilliant fire, as in the figure. All the cases and stars must be fired at once. This piece should be fixed high from the ground.

Illuminated Pyramid, with Archimedian Screws, a Globe and Vertical Sun,

May be made of any size: one made according to the dimensions of Fig. 3d, will be a good proportion, whose height is 21 feet; from *C* to *D*, 6 feet; from *E* to *F*, 9 feet: the space between the rails must be 6 inches, and the rails as thin as possible: in all the rails stick port-fires at 4 inches distance. The Archimedian screws, *G*, *K*, are nothing more than double spiral wheels, with the cases placed on their wheels horizontally, instead of obliquely. The vertical sun, *I*, need not consist of more than 12 rays, to form a single glory. The globe at top must be made in proportion to the pyramid, which being prepared according to the preceding directions, place your leaders so that all the illuminating port-fires, screws, globe, and sun, may take fire together. The pyramid must be supported by the 2 sides, and by a support brought from a pole, which must be placed 2 feet from the back of the pyramid, that the wheels may run free,

Rose-Piece and Sun.

A rose-piece may be used for a mutation of a regulated piece, or fired by itself: it makes the best appearance when made large; if its exterior diameter be 6 feet, it will be a good size. Fig. 4. shews the manner it appears in before it is fired. Let the exterior fell be made of wood, and supported by 4 wooden spokes: all the other parts, on which the illuminations are fixed, must be made of strong iron wire: on the exterior fell place as many $\frac{1}{2}$ lb. cafes of brilliant charge as you think proper, but the more the better; for the nearer the cafes are placed, the stronger will be the rays of the sun: the illuminations should be placed within 3 inches of each other; they must be all fired together, and burn some time before the sun is lighted; which may be done by carrying a leader from the middle of one of the illuminations, to the mouth of one of the sun cafes.

Transparent Stars with Illuminated Rays.

Plate 7, Fig. 5th, represents an illuminated star. Let the diameter from A to B be 2 feet, and from C to D, 7 feet. First make a strong circular back or body of the star, 2 feet diameter, to which you fix the illuminated rays: in the centre of the front of the body fix a spindle, on which put a double triangular wheel, 6 inches diameter, clothed with 2 ounce cafes of brilliant charge; the cafes on this wheel must burn but 1 at time. Round the edge of the body nail a hoop made of thin wood or tin: this hoop must project in front 6 or 7 inches: in this hoop cut 3 or 4 holes to let out the smoke from the wheel. The star and garter may be cut out of strong paste-board, or tin, made in this manner: Cut a round piece of pasteboard, or tin, 2 feet diameter, on which draw a star, and cut it out; then over the vacancy paste Persian silk; paint the letters yellow; 4 of the rays yellow, and 4 red; the cross in the middle may be painted half red, and half yellow, or yellow and blue. This

transparent star must be fastened to the wooden hoop by a screw, to take off and on; the illuminated rays are made of thin wood, with tin sockets fixed on their sides within 4 inches of each other; in these sockets stick illuminating port-fires; behind the point of each ray fix a half-pound case of grey, black, or Chinese fire.

N. B. The illuminated rays to be lighted at the same time as the triangular wheel, or after it is burnt out; which may be done by a tin barrel being fixed to the wheel, after the manner of those in the regulated pieces. Into this barrel carry a leader from the illuminated rays, through the back of the star; which leader must be met by another, brought from the tail of the last case on the wheel.

Transparent Table Star illuminated.

Fig. 6th represents a table star, whose diameter, from E to F, is 12 feet; and from E to I, 4. This proportion, observed on each side, will make the centre frame 4 feet square: in this square fix a transparent star, as in the figure. This star may be painted blue, and its rays made as those of the flaming stars described in page 113. The wheel for this star may be composed of different coloured fires, with a change or 2 of slow fire; the wheels a, a, a, a, may be clothed with any number of cases, so that the star wheel consists of the same: the illuminating port-fires, which must be placed very near each other on the frames, must be so managed as to burn as long as the wheels, and lighted at the time.

The Regulated Illuminated Spirali Piece, with a projected Star Wheel illuminated.

This piece is represented by Fig. 7. and is thus made. Have a block made 8 inches diameter; in this block screw 6 iron spokes, which must serve for spindles for the spiral wheels: these wheels are made as usual, each 1 foot 6 diameter,

6 diameter, and 3 feet in height: the spindles must be long enough to keep the wheels 4 or 5 inches from one another: at the end of each spindle must be a screw nut, on which the wheels that hang downwards will run; and on the spindles which stand upwards must be a shoulder, for the blocks of the wheels to run on.

The projected star-wheel must turn on the same spindle on which the large block is fixed: this spindle must be long enough to allow the star-wheel to project a little before the spiral wheels: the exterior diameter of the star-wheel must be 3 feet 5. On this wheel fix 3 circles of iron wire, and on them port-fires; on the block place a transparent star, or a large 5-pointed brilliant star. The cases on this wheel may burn 4 at once, as it will contain near twice the number of one of the spiral wheels: the cases on the spiral wheels must be placed parallel to their fells, and burn 2 at a time.

A New Figure-Piece illuminated with Five-Pointed Stars.

The construction of this piece is very easy, as shewn by Fig. 8, whose diameter from B to C is 8 feet, and from D to E 2 feet: the vertical wheel in the centre must be 1 foot diameter, and consist of 6 four-ounce cases of different coloured charge, which cases must burn double: on the frames fix 5-pointed brilliant or blue stars, rammed 4 inches with composition: let the space between each star be 8 inches; at each point fix a gerbe, or case of Chinese fire. When to be fired, let the gerbes, stars, and wheel, be lighted at the same time.

The Star-Wheel Illuminated.

This beautiful new-invented piece is shewn in Plate 8, Fig. 9. its exterior fell is made of wood, 3 feet 6, or 4 feet diameter: within this fell, form with iron wire 3 circles, one less than the other, so that the diameter of the least
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may be about 10 inches: place the port-fires on these fells with their mouths inclining outwards, and the port-fires on the points of the star with their mouths projecting in front: let the exterior fell be clothed with 4-ounce cases of grey charge: these cases must burn 4 at a time, and be lighted at the same time as the illuminations.

Pyramid of Flower-Pots.

Fig. 10. represents this curious piece, which must be made thus. Let the distance from A to B be 6 feet, and from one rail to the other 2: on the bottom rail fix 5 paper mortars, each $3\frac{1}{2}$ inches diameter: these mortars load with serpents, crackers, stars, &c.

In the centre of each mortar fix a case of spur-fire: on the second rail fix 4 mortars, so as to stand exactly in the middle of the intervals of them on the bottom rail; on the third rail place 3 mortars; on the fourth, 2; and on the top of the posts, 1: the bottom rail must be 6 feet long: all the mortars must incline a little forwards, that they may easily discharge; and the spur-fires rammed exactly alike, that the mortars may all be fired at the same time. Having prepared your pyramid according to the preceding directions, carry pipes of communication from one spur-fire to the other.

The illuminated Regulating Piece.

Fig. 11. represents one half of this piece. A, A, A, A, are flat wooden spokes, each 5 feet long; and at the end of each place a vertical wheel, 10 inches diameter, clothed with 6 4-ounce cases of brilliant fire: these cases must burn but 1 at a time: on 2 of the spokes of each wheel place 2 port-fires, which must be lighted with the first case of the wheel; on each spoke A, A, &c. behind the wheels, place 6 cases of the same size as them on the wheels; these cases must be tied across the spokes with their mouths all one way, and be made to take fire successively one after the other, so that they may assist the whole pieces to turn round.

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The diameter of the wheel B must be 2 feet 6, and its fell made of wood, which must be fixed to the large spokes: on this wheel place 24 cases of the same sort as them on the small wheels; these cases must burn 4 at a time: in this wheel make 3 circles with iron wire, and on them place illuminating port-fires, as in the figure: the star points on the large spokes may be made of thin ash-hoops; the diameter of these points close to the centre wheel must be 11 inches: on these points place port-fires, at $3\frac{1}{2}$ inches distance one from the other.

Fig. 12. represents the blocks of this piece. The diameters of these blocks, at A and B, must be 8 inches; and C and D, $4\frac{1}{2}$ inches: the length of each of these blocks must be 6 inches: at the small ends of these blocks fix an iron wheel 5 inches diameter, which wheels must have teeth, to turn the wheel E: this wheel is fixed on a small spindle screwed into the large spindle, which goes through the two blocks, and on which they run.

Supposing Fig. 11. to be on the block A, in Fig. 12, and to turn to the right, and another piece of the same construction on the block B, with its fires placed so as to turn it to the left; you will find them move very true and fast, by the help of the 3 iron wheels, which serve to regulate their motions, as well as to assist them in turning: let the iron circles in the front of the great wheels be of different diameters, so that when fired there may appear 6 circles. When this piece is fired, all the wheels and illuminations must be lighted at one time.

To fix a Sky-Rocket with its Stick on the Top of another.

Rockets thus managed make a pretty appearance, by reason of a fresh tail being seen when the second rocket takes fire, which will mount to a great height. The method of preparing these rockets is thus: Having filled a two-pounder, which must be filled only half a diameter above the piercer, and in its head not more than 10 or 12 stars; the

the stick of this rocket must be made a little thicker than common, and when made, cut it in half the flat way, and in each half make a groove, so that, when the 2 halves are joined, the hollow made by the grooves may be large enough to hold the stick of a half-pound rocket; which rocket make and head as usual; the stick of this rocket put into the hollow of the large one, so far that the mouth of the rocket may rest on the head of the two-pounder; from whose head carry a leader into the mouth of the small rocket; which being done, your rockets will be ready for firing.

A New Method of Placing Leaders.

The placing leaders on small cases, or illuminations, is a much quicker, stronger, and more expeditious way than that of using pins; which method has been practised till lately. Your port-fires being filled within about $\frac{3}{8}$ ths of an inch of the top, bore with an awl a hole thro' each side of the case, close to the composition; then fill the mouths of the cases with meal powder wetted with spirit of wine: when you have thus prepared your cases, fix them on your works; then take an empty leader, and lay it on the mouths of as many cases as it will reach; then, with your finger nail, mark the leader exactly in the middle of the mouth of each case; then at each mark, with a pair of scissars, cut a bit out of the pipe, so that, when you put in the quick-match, it may be seen. This done, lay the leader on the cases again, with that side on which the match is seen downwards; then take some small twine, and put it through the holes in the mouths of the cases, and tie on the leader: do this to every case, and cover them with single pasted paper. By making use of this method your works may be made very clean, there being no occasion to put dry meal powder in the mouths of the cases, which always soils the works, and prevents the paste from sticking.

Here

FIREWORKS.

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Here I have taught the method of rolling, pinching, and filling all sorts of cases; the manner of pulverizing, mixing, and preparing, all compositions used in artificial fire-works; also the method of placing leaders, clothing wheels, fixed pieces, &c. in so plain a manner, that all fire-works may be made without any further instructions. A variety of pyrotechnical representations only depends on the genius of the maker, by fixing different cases and fires on works of various forms, of which there are many more.

But as those I have given are the principal, I shall conclude with Mr. Muller's Laboratory and a few of his Mines; which are all that was wanting to complete this work.

Mr.

Mr. MULLER on LABORATORY WORKS.

MY design is not to give here any more than what is just necessary for the young Artillerist to know in the course of his duty, referring that part which regards the Fire-works made for Rejoicing to the excellent Treatise on Artificial Fireworks, wrote by *Robert Jones*, who gives all that can be said on that subject, and has himself practised every part of it.

Grapeshot.

The number of shot in a grape varies according to the service or size of the guns: in sea-service 9 is always the number; but by land it is increased to any number or size; from an ounce and a quarter in weight, to 3 or 4 pounds. It has not been determined, what number or size answers best in practice; which I think should be tried: for it is well known, that they oft scatter so much, that only a small number take place. It would not be a useless experiment, to try at what distance they would do most execution, and what is the best charge of powder. In sea-service, the bottoms and pins are made of iron, whereas those used by land are of wood: for what reason this distinction is made, I cannot tell, unless that these iron bottoms are supposed to destroy the riggings of ships more than the wooden.

To make grape-shot, a bag of coarse cloth is made just to hold the bottom which is put into it; then as many shot as the grape is to contain; and with a strong pack-thread they are quilted to keep the shot from moving, and when they are finished are put into boxes for carriage. When the shot are small, they are put into tin boxes that fit the bore of the gun. Leaden bullets are likewise used
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in the same manner. It must be observed, that whatever number or sizes of the shots are used, they must weigh with their bottoms and pins nearly as much as the shot of the piece.

Cartridges.

The loading and firing guns with cartridges is done much sooner, and less liable to accidents, than with loose powder. They are made of various substances, such as paper, flannel, parchment, and bladders. When they are made of paper, the bottoms remain in the piece, and accumulate so much, that the priming cannot reach the powder; and therefore they must be drawn from time to time, which retards the service. They have another inconveniency, which is, they retain the fire; and, if particular care is not taken in spunging the piece, they will set fire to the next cartridge, and the gunner that puts it into the piece will be in danger of losing a hand or arm, as has sometimes happened. When they are made of parchment or bladders, the fire shrivels them up, whereby they enter into the vent, and become so hard, that the priming iron cannot remove them so as to clear the vent. Nothing has been found hitherto to answer better than flannel, and is the only thing used at present, because it does not keep fire, and therefore not liable to accidents in the loading; but as the dust of powder passes through them, a parchment cap is made to cover them, which is taken off before this is put into the piece.

The best way of making flannel cartridges is, in my opinion, to boil the flannel in size; this will prevent the dust of the powder from passing through them, and renders them stiff, and more manageable; for without this precaution they are so pliable, that when they are large, and contain much powder, they are very inconvenient in putting them into the piece. The Saxon, who introduced our present light field pieces, had a particular method of preparing cartridges, which was such, that when laid into the fire they would not burn; and yet, by dipping them

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into water before they were put into the piece, would take fire as quick as powder; but how he did it, nobody could tell; for he would not part with his secret.

In quick firing the shot is fixed to the cartridge by means of a wooden bottom, hollowed on one side so as to receive nearly half the shot, which is fastened to it by two small slips of tin crossing over the shot, and nailed to the bottom; and the cartridge is tied to the other end of this bottom. They are fixed likewise in the same manner to the bottoms of the grapeshot, which are used in field pieces.

Portfires.

Portfires are used sometimes instead of matches, to set fire to powder or compositions; and are distinguished into wet and dry. The composition of wet portfires is, saltpetre 4, sulphur 1, and mealed powder 4; when the composition is well mixed and sieved, it is to be moistened with a little linseed oil, and well rubbed with the hands till all the oil is well mixed with the composition. The composition of dry portfire is, saltpetre 4, sulphur 1, mealed powder 2, and antimony 1. These compositions are drove into small paper cases, and so kept till used.

Quickmatch

Is made with three cotton strands drawn into length, and put into a kettle covered with white wine vinegar, and a quantity of saltpetre and mealed powder, and boiled till well mixed. Others put only saltpetre into the water. After that, it is taken out hot, and laid in a trough where some mealed powder, moistened with spirits of wine, is thoroughly wrought into the cotton, by rolling it backwards and forwards with the hands: when this is done, they are taken out separately, and drawn through mealed powder, then hung upon a line till dry.

Tubes used in quick Firing.

These tubes are here made of tin: their diameter is two tenths of an inch, to enter into the vent of the piece; about 5 or 6 inches long, with a cap above, and cut slanting below in the form of a pen; and the point is strengthened with some folder, that it may pierce the cartridge. Through this tube is drawn a quickmatch, and the cap is filled with mealed powder moistened with spirit of wine. To prevent the mealed powder from falling out by carriage, a cap of paper is tied over it, which is taken off when used; but latterly this cap is made of flannel steeped in spirits of wine, with saltpetre dissolved in it; there is no occasion to take it off, since it takes fire as quick as loose powder.

An objection is made against these tubes, which is, that the tin is apt to spoil the quickmatch when they are kept for some time; and it is imagined, that salt water would soon corrode them, therefore not proper to be used on board of ships; this however has not been tried. The French use a small reed, to which is fixed a wooden cap about two inches long, filled with mealed powder moistened with spirit of wine: a small hole is made through them the size of a needle, through which the fire darts with great violence, and gives fire to the cartridge, which must be pierced with the priming iron. These tubes may be kept a great while without being spoiled; but the piercing the cartridge retards the quickness of firing. The forementioned Saxon made his of copper, tapering towards the end, so as to enter the vent about half an inch, which is made so far in the same form, and the rest very narrow: they are filled in the same manner as the French, and when fired, the flame darted through the cartridge without being pierced.

Fuzes for Shells and Hand-Grenades.

The composition for fuzes is saltpetre 3, sulphur 1, and mealed powder 3, 4, and sometimes 5, according as required to burn quicker. Fuzes are chiefly made of very dry beech wood, and sometimes of hornbeam taken near the root; the upper part of that wood splits very easily. They are turned rough, and bored at first, and then kept for several years in a dry place: the diameter of the hole is about a quarter of an inch, a little more or less is of no consequence; the hole does not go quite through, leaving about a quarter of an inch at the bottom; and the head is made hollow in the form of a bowl. The composition is drove in with an iron driver, whose ends are capped with copper to prevent the composition from taking fire; and equally hard as possible; the last shovel-full being all mealed powder, and two strands of quickmatch laid across each other being drove in with it, the ends of which are folded up into the bowl, and a cap of parchment tied over it till used. Observe, that, when shells are to be thrown at a small distance, the composition should be made quicker than when they are to be thrown at a greater; for, by cutting them so as to burn but a short time, they might not be long enough to be well fixed into the shell, by which the blast of the powder in the chamber would blow them out, without the shell being able to burst. It must likewise be observed, that the custom of fixing the shells at home is very bad, since it is not known how long they should burn; and if they do not burst as soon as they fall, the execution is but trifling. Another disadvantage attends this practice; when they are carried into a hot climate the wood shrinks, though ever so dry before; and the fuzes loosen so much, that they fall out in the flight of the shell before it falls to the ground.

When the fuzes are to be drove, the lower end is cut off in a slope, so as the composition may give fire to the powder; and they must have such a length, as to burst nearly as soon as the shell touches the ground. When the

the distance of the battery from the object is known, the time of the shell's flight may be computed nearly; which being known, the fuze may be cut accordingly, by burning 2 or 3, and making use of a watch, or a string by way of a pendulum.

Before shells are loaded, they must be well searched within and without by means of a copper grater, to see if there are no holes or cavities in them; after that put them into a tub of water, to cover them, with an empty fuze drove into them; and the mouth of a bellows, being introduced into the fuze, and worked, will cause bubbles in the water, if there are any holes in the shell; but if no bubbles appear, it is a sign the shell is sound and fit for service.

When loaded, care must be taken that they are very dry within; and if the spike which supports the corp when they are cast, and which remains in them, is not beat down, it must be done then, otherwise it would split the fuze. Then the powder is put into it with a funnel, and not quite filled, that the fuze may have room to enter, which fuze is pressed in at first by the hand as far as it will go, and then drove with a mallet as hard as possible, taking care not to split it; for if the least crack was in it, the composition would give fire to the powder, and the shell burst either in the mortar or the air, and do no execution.

It is a query how much powder is to be put into a shell, so as to make it burst in most pieces. It is agreed by most officers that they should not be quite filled; one that has taken most pains to find it out, is of opinion that they should be filled within one third part of what they can hold.

Lieutenant Pirle, a very ingenious mechanic, lost in the Dodington some years ago going to the East-Indies, had found out a method, so that as soon as the shell touched the ground it burst; but being too modest a man, had not the assurance to propose it to the master general of the ordnance, whereby the world was deprived of a most useful invention.

If the fuzes are to be kept for some time after they are drove, the top must be covered with a mixture of pitch 2, rosin 1, and bees wax 3, whereby no air can come to the composition; and it will keep as long as you please.

Carcasses.

None but round carcasses are used at present, the flight of the oblong are so uncertain, that they are quite laid aside. The composition is pitch 2, saltpetre 4, sulphur 1, and corned powder 3. When the pitch is melted, the pot is taken off, and the ingredients well mixed put in; then the carcass is filled with as much as can be pressed in.

Light Balls to discover the Enemy's Works.

There are various sorts described. Some made of tow dipped into a composition of sulphur, pitch, rosin, and turpentine; and worked up into a ball. Others take a ball of stone or iron, which is covered with several coats of composition, much like that before mentioned, till of a proper size; the last coat is to be of grained powder. But the best sort, in my opinion, is to make a shell of paper the size of the mortar, and to fill it with a composition of an equal quantity of sulphur, pitch, rosin, and mealed powder; which being well mixed, and put in warm, will give a clear fire, and burn a considerable time.

There are many more things used in the defence of a breach; such as sacks filled with powder, bottles, barrels, &c. but as the chief intent of all these is to set fire, and blow up the assailants, and which every military gentleman may easily execute, we shall say no more here about them; our design being to instruct the young artificer in the essential parts of his business; and to make him master of these matters, he must work in the laboratory; for practice is the best master.

Fireship,

Fireship, how to prepare it.

From the bulk-head at the fore-castle to a bulkhead to be raised behind the main chains, on each side and across the ship at the bulkheads, is fixed, close to the ship sides, a double row of troughs, 2 feet distance from each other, with cross troughs quite round, at about $2\frac{1}{2}$ feet distance; which are mortised into the others. The cross troughs lead to the sides of the ship, to the barrels and to the port-holes, to give fire both to the barrels and the chambers, to blow open the ports; and the side-troughs serve to communicate the fire all along the ship and the cross troughs.

The timbers of which the troughs are made are about 5 inches square; the depth of the troughs half their thickness, supported by cross pieces at every 2 or 3 yards, nailed to the timbers of the ship, and to the wood work which incloses the fore and main masts, and takes in an oblong in the middle of the deck, extending to the outside of both the masts, and in breadth is near one half of the deck; and is what makes the carpenter's room for his stores. The decks and troughs are all well paved with melted rosin.

On each side of the ship are cut out 6 small port holes, in size about 15 by 18 inches, the ports opening downwards, are close caulked up: against each port is fixed an iron chamber, which, at the time of firing the ship, blows open the ports and lets out the fire. At the main and fore chains on each side is a wooden funnel fixed over a fire barrel, and comes through a scuttle in the deck up to the shrouds to give fire to them; and between them are cut two scuttles on each side the ship, which also serve to let out the fire. Both funnels and scuttles must be stoppt with plugs, and have sail-cloth or canvas nailed close over them, to prevent any accident happening that way by fire to the combustibles below.

The port-hole, funnels, and scuttles, not only serve to give the fire a free passage to the outside and upper parts

parts of the ship, and its rigging, but also for the inward air, otherwise confined, to expand itself, and push through those holes at the time of the combustibles being on fire, and prevent the blowing up the decks, which otherwise must of course happen from such a sudden and violent rarefaction of the air as will then be produced.

In the bulkhead behind on each side is cut a small hole, large enough to receive a trough of the same size as the others; from which, to each side of the ship, lies a leading trough, one end coming through a sally port cut through the ship's side; and the other, fixing into a communicating trough that lies along the bulkhead, from one side of the ship to the other, and being laid with quickmatch only, at the time of firing either of the leading troughs, communicates the fire in an instant to the contrary side of the ship, and both sides burn together. The communicating trough, which is fixed to the bulkhead, and the leading troughs, are the same size as the others.

Manner of preparing Stores.

Fire Barrels.

The form of the barrels should be cylindric, both upon the account of that make answering better for filling them with reeds, and for stowing them on board between the troughs; their inside diameters are sufficient, if about 21 inches, and their lengths 33. The bottom parts are first filled with short double-dipt reeds set on end, and the remainder with fire-barrel composition well mixed and melted, and then poured over them.

There are 5 holes of $\frac{3}{4}$ inch diameter, and 3 inches deep, made with a drift of that size in the top of the composition while it is warm; one in the centre, and the other 4 at equal distances round the sides of the barrel. When the composition is cold and hard, the barrel is primed by well driving those holes full of fuze composition to within an inch of the top; then fixing in each
hole

hole a strand of quickmatch twice doubled, and in the centre hole 2 strands the whole length; all which must be well set or drove in with mealed powder; then lay the quickmatch all within the barrel, and cover the top of it with a dipt curtain, fastened on with a hoop to slip over the head, and nailed on.

The barrels should be made very strong, not only to support the weight of the composition before firing, in removing and carrying them about, but to keep them together at the time they are burning; for if the staves are too slight and thin, and should burn too soon, so as to give way, the remaining composition would be apt to separate, and tumble upon the deck, which would destroy the designed effect of the barrel, which is to carry the fire aloft.

Iron Chambers.

They are 10 inches long, and 3.5 in diameter; and breeched against a piece of wood fixed across the port-holes, and let into another lying a little higher; when loaded they are filled almost full of corned powder, and have a wooden tompon well drove into their muzzles; are primed with a small piece of quickmatch thrust through their vents into the powder, with a part of it hanging out; and when the ship is fired, they blow open the ports, which either fall downwards, or are carried away, and so give vent for the fire out of the sides of the ship.

Curtains

Are made of barras about $\frac{3}{4}$ of a yard wide, and one yard in length; when they are dipped, 2 men with each a fork (on a shaft of the same size, with 1 prong in each if made on purpose) must run each of their prongs through a corner of the curtain at the same end; then dip them into a large kettle of composition well melted; and when well dipped, and the curtain extended to its full breadth,

whip it between 2 sticks of about 5.5 feet long, and 1.5 inches square, held close by 2 other men to take off the superfluous composition hanging to it; then immediately sprinkle saw-dust on both sides to prevent its sticking, and the curtain is finished.

N. B. A copper fixed with a furnace is much better than a kettle that is not fixed, because it must be taken off from the fire for every dipping, to prevent the stripped off composition from falling into it, which would unavoidably give fire to the whole; and renders the use of a kettle tedious that way.

Reeds

Are made into small bundles of about 12 inches in circumference, cut even at both ends, and tied with 2 bands each; the longest sort is 4 feet, and the shortest 2.5; which are all the lengths that are used. 1 part of them are single dipped, only at 1 end; the rest are double dipped, that is, at both ends. In dipping, they must be put about 7 or 8 inches deep into a copper or kettle of melted composition; and when drained a little over it, to carry off the superfluous composition, sprinkle them over a tanned hide with pulverized sulphur, at some distance from the copper.

Bavins

Are made of birch, heath, or other sort of brush-wood, that is both quickly fired and tough; in length 2.5 or 3 feet, the bush-ends all laid one way; and the other ends tied with 2 bands each. They are dipped and sprinkled with sulphur the same as reeds, only that the bush-ends alone are dipped, and should be a little closed together by hand as soon as done, before they are sprinkled, to keep them more close, to give a stronger fire, and to keep the branches from breaking off in shifting and handling them.

Disposition

Disposition of the Stores on board, when laid for firing.

The fire-barrels are placed under the funnels and scuttles, 1 to each; and are fixed between the cross troughs leading to the sides of the ship, and lashed to them, and well cleeted to the deck. Those at the funnels give fire to the main and fore shrouds; the rest rise over the deck through the scuttles. The plugs must be taken out of the funnels and scuttles before the ship is fired, and the curtains covering the fire-barrels cut open and rolled back, the quickmatch spread, and the top of the barrels well salted with priming composition. The curtains are nailed to the beams of the upper deck, hanging down over the troughs, bavins, and reeds.

The priming composition; a part of it is laid along the troughs, and the rest, after laying of the reeds and bavins, is regularly strewed over all. The short reeds, double dipped, with some of the single dipped, are laid along both the sides and cross troughs, and communicate the fire both to the barrels and chambers. The rest of the single dipped reeds and bavins are set about the fire barrels, and to the sides of the ship; and some flung upon the deck.

The quickmatch is laid 2 or 3 strands thick upon the reeds in the troughs, and about the fire-barrels and chambers, to communicate a general fire at once. The reeds in the troughs with the quickmatch are lashed on, to prevent their falling out by the rolling of the ship.

The leading troughs are both laid with 4 or 5 strands of quickmatch; as is likewise the communicating trough, that by firing either of the leading troughs, the communicating trough may carry the fire to the other side of the ship; which then runs along the troughs by the quickmatch on both sides, and gives fire to the whole in an instant.

The Composition made use of for Curtains, Reeds, and Bavins, are all the same, viz.

Pitch	14	} N. B. For want of tar take 3 lb. of tallow.
Sulphur	7	
Rosin	7	
Tallow	2	
Tar	1	

Fire-Barrel Composition for one Barrel.

Corned powder	_____	_____	lb. 120
Pitch	_____	_____	60
Tallow	_____	_____	10

Divide the composition into 5 pots; the pitch and tallow must be first thoroughly melted. Tallow well the outside of the pot to take off the heat; and then put in the powder by small quantities, stirring it well about.

Priming Composition for one Barrel.

Corn powder	_____	_____	lb. 100
Petre	_____	_____	50
Sulphur	_____	_____	40
Rosin	_____	_____	6
Oil	_____	_____	pints 3

Take 20 lb. of powder, which mix well with the petre, sulphur, and rosin; work them well together, breaking it well in working; then put the rest of the powder in by degrees, and work it all together: spread it in a trough, and through a hair sieve run 3 pints of oil all over it: then work it well together, and run it through a cane sieve.

N. B.

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N. B. In the following estimate for the quantity of stores requisite, the reeds for the barrels are not included; it will take 100 short double dipped more than these specified; but their value is included in the article of barrels.

Stores for a Fireship of 150 Tons.

	Numb.	Value.
		l. s. d.
Fire barrels	8	80 : 0 : 0
Iron chambers	12	12 : 0 : 0
Priming composition barrels	3½	21 : 0 : 0
Quickmatch barrels	1	3 : 0 : 0
Curtrains dipped	30	3 : 0 : 0
Long reeds fingle dipped	150	10 : 15 : 0
Short reeds { double dipped	75	2 : 18 : 9
{ fingle dipped	75	1 : 17 : 6
Bavins fingle dipped	209	10 : 0 : 0
		144 : 11 : 3

Quantity of Composition for preparing the Stores of a Fireship.

	pe- tre.	fulp	corn pow.	pit ch	ro- fin	tal low	tar	oil pts.
For 8 barrels	0	0	960	480	0	80	0	0
For 3.5 barrels of priming composition	175	140	350	0	21	0	0	11
For the curtains, bavins, and reeds for the ship, and sulphur for salting them	0	200	0	350	175	50	25	0
Total	175	340	1310	830	196	130	25	11

Total weight of the composition 3017, equal to C. 28: 3: 2.

Composition

Composition allowed for the reeds for the barrels one fifth of the whole of the last article, which is equal to 163 lb. and makes the whole 3177 pounds, or C. 28:1:13.

We have completed the several branches of the Art of War, in eight volumes in octavo, as promised. We have done all that lies in our power to treat them with perspicuity and clearness, in order to reduce the whole to as small a compass as possible, for the sake of those military gentlemen who have an inclination to be masters of their business in a short time. We could not enlarge upon every particular so much as might be necessary; yet whoever renders himself master of what we have said, will find that nothing very material has been neglected.

Grains	Drums	Barrels	Boxes	Trunks	Cartridges	Shells	Minerals	Saltpetre	Sulphur	Charcoal	Iron	Copper	Lead	Gunpowder	Composition	Weight	Value
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

M. BELIDOR's New Method of MINING.

To which is added,

M. VALLIERE on COUNTERMINES.

THIS work is, to shew the fallacy of miners in general, in regard to the effect of powder confined in mines, and to establish the true theory of mines, upon a solid foundation; which being likewise confirmed by many unexceptionable experiments, cannot fail of meeting with the approbation of every unprejudiced reader: as to those who find fault with every thing new, that seems to contradict an old established opinion, though ever so erroneous, their censures will not be regarded; nor will any objection whatever be admitted, unless supported by well attested experiments.

If you imagine a large globe of earth homogeneous in all its parts, and a certain quantity of powder lodged in its centre, so as to produce a proper effect without bursting the globe; by setting fire to the powder, it is evident, that the explosion will act all round, to overcome the obstacles which oppose its motion; and as the particles of earth are porous, they will compress each other in proportion as the flame increases, and the capacity of the chamber increases likewise. But the particles of earth next to the chamber will communicate a part of their motion to those next to them, and those to their neighbours; and this communication will thus continue in a decreasing proportion, till the whole force of explosion is entirely spent, and the particles of earth beyond this term will remain in the same state as they were. The particles

particles of earth that have been acted upon by the force of explosion will compose a globe which M. Belidor calls the *Globe of Compression*.

The foregoing experiment is easily comprehended; but when powder is lodged in a mine, where the weight of the earth in the line of least resistance, is less than at the sides and underneath, it seemingly appears, that as soon as the force of explosion reaches the surface of the ground, it would throw up a certain quantity of earth, and leave a hollow in the form of a frustum of a cone, with no other effect upon the sides or bottom; as likewise, that when the mine is overcharged, the base of the excavation, instead of increasing, would rather diminish, because the force of explosion being greater would sooner reach the extremity of the line of least resistance: it is in this light, that all practical miners have hitherto considered the action of powder lodged in mines; and from thence concluded, that a certain charge will form an excavation, whose greatest diameter shall be double the line of least resistance; a less quantity raise the earth only a little, and a greater throw the earth up higher, and diminish the diameter of the excavation instead of increasing it.

As absurd as such an opinion may be, that a greater force produces a less effect than a more moderate one; yet it has prevailed amongst all the practical miners in Europe; without considering that there may be physical causes in nature, with which they were unacquainted, and that no theory of this kind should be admitted unless supported by well attested experiments.

M. Belidor made several experiments with various charges at la Fere, from which it appeared, that the greatest diameter of an excavation may not only be made double, but treble or quadruple; yet some old miners of note, who were present, could or would not believe it, though they had seen it, much less those who were absent. These experiments shewed that the diameter of the excavation could be made greater than was imagined; but for what reason, was not hitherto known, till M. Belidor demonstrated it, in the Memoirs of the Academy of Sciences

ences at Paris, in 1762, from which this work has been extracted.

To explain the reasons on which the principles of mines are grounded, it is necessary to consider not only the resistance which the weight of the earth and the cohesion of the parts make against the force of explosion, but likewise the pressure of the atmosphere, which is so great as to counterbalance a column of water of the same base, and whose altitude is 33 feet, which answers nearly to a height of a middling soil of about 22 feet: so that if the line of least resistance of a mine is 10 feet, the force of explosion must not only overcome the weight of 10 feet of earth above it, but 32 feet, properly speaking. It is to be observed, that this weight resists the force of explosion no longer than till the mine bursts, and the explosion gets a communication with the air, because then the pressure of the air ceases.

Plate I. fig. 1. As the powder does not fire all at once, but gradually; so the force of explosion increases proportionally, and condenses the earth all round in a spheric form, as has been observed, till this force overcomes the resistance of the earth and atmosphere, which cannot happen before the earth rises in the middle into a spheric form, and the radius (C A) of explosion extends to the surface (A B) of the earth; and then the explosion getting a free communication with the air, raises the earth to a considerable height, and forms an excavation of a curved-lined figure, such as A E B; the point C represents the centre of the powder or chamber.

It is a known principle, established by facts, that the force of explosion is always proportional to the quantity of powder fired; and as the force of explosion acts in a spheric form, and spheres are as the cubes of their radii, it is evident, that the forces of explosion, or the quantities of powder fired, are proportional to the cubes of their radii.

This proportion will always hold good in an uniform soil, but varies according to the density: and if the chamber of a mine be placed on a rock, or some other hard substance, the diameter of the excavation will be greater than

than it would have been otherwise; because the force of explosion being resisted downwards, will act with a greater violence towards the sides and upwards. A mine placed in a soil of a greater density and tenacity than another of the same depth, requires a greater charge in proportion; but it must be observed, that the tenacity is not proportional to the surface of the excavation, as M. de Valliere and some others pretend, but to the solid itself, as we have shewn in page 221 of our Attack, where we treat of the proper charges of mines.

To find a proper charge of a mine in any soil, so as to produce a given diameter, an experiment mine must be made in the same soil, sufficiently charged, so as to produce a proper effect, and the line of least resistance exactly measured, as well as the diameter of the opening, by which the radius CA of the globe of compression will be found: then say, *the cube of the radius of the globe of compression found by the experiment, is to the cube of the radius of the proposed mine, as the charge of the experiment mine is to the charge required.*

And to find the diameter of a mine whose charge is given, say, *the charge of the experiment mine is to the given charge, as the cube of the radius of the first is to the cube of the radius of the second.* From whence the diameter required is found by this equation, $CA^2 - CD^2 = AD^2$.

Amongst some mines made at la Fere, one was charged with 170lb. and another with 300lb. the line of least resistance of both was 10 feet: the diameters being measured, the first was found 20 feet, and the second 27. Now to find this last diameter by the theory, add the squares of 10, the line of least resistance, to the square of 10, half the diameter 20, which gives 200, for the square of the radius whose cube is 2828: then $170 : 300 :: 2828 : 4990$, this fourth term is the cube of the radius of the second mine, whose root is 17: and if from the square 289 of this root, the square 100 of the line of least resistance be subtracted, the square root of the difference will be 13.7 and 27.4, twice this root, the diameter

diameter required: which is nearly the same as has been found by the experiment.

Let a mine be loaded with 980lb. in the same soil, and the line of least resistance 15 feet: then $170:980::2828:16302$: for the cube of the radius, and its logarithm 4.21224, multiplied by 2, and divided by 3, gives 2.80826; for the logarithm of the square of the radius, which answers to the number 643, from which subtracting 225, the square of the line of least resistance, and taking the square root of the difference 418, we get 20.4, and twice that number gives 40.8, which exceeds 40 feet 2 inches, found by experiment, by about 5 inches.

Having made another mine in the same soil, loaded with 3600lb. of powder, and of the same depth, viz. 15 feet, the diameter was found to be 70 feet: now if $170:3600::2828:59887$, this fourth term is the cube of the radius, whose logarithm, 4.77733, multiplied by 2 and divided by 3, gives 3.184888 for the logarithm of the square, which therefore is 1530; from this subtracting 225, the square of the line of least resistance, the square root of the difference 1305 will be 36, and twice this number 72 the diameter; which is 2 feet more than that found by experiment.

M. Belidor, finding the diameters of mines loaded with great charges, greater by computation than by experiments, imagines that it was owing to the cubical chambers, by which the quantity of earth above them is less in proportion than in small ones: but whether this reason is just, or that the diameter and the line of least resistance have not been rightly measured, is not certain; for a friend of mine found the contrary in some very accurate experiments he made.

Having given an account in page 232 of our Attack, of some experiments formerly made at la Fere, and computed their diameters from the parabolic figure, we shall here compute the same diameters from the globe of compression. The first was loaded with 120, the second 160, the third 200, the fourth 240, the fifth 280, the sixth 320, and the seventh with 360: the line of least resistance was

M

10 feet

10 feet in all of them; the diameters were found to be, 1ft, $22\frac{2}{3}$, 2d, 26, 3d, 29, 4th, $31\frac{1}{4}$, 5th, $33\frac{1}{2}$, 6th, 36, 7th, 38 feet. Now taking the diameter of any one as known, for example, that of the second 26, whose globe of compression will be found to be 4412; then as the globes of compression are proportional to the charges, they will be, 1ft, 3309; 3d, 5515; 4th, 6618; 5th, 7721; 6th, 8824; 7th, 9927: the squares of their radii, 1ft, 225.05; 3d, 312.15; 4th, 352.49; 5th, 390.64; 6th, 427.02; 7th, 461.9; and the radii of the bases, 1ft, 11.05; 3d, 14.56; 4th, 15.88; 5th, 17.04; 6th, 18.08; 7th, 19.02; whence the diameters are, 22.1; 29.12; 31.76; 34.08; 36.16; 38; which shews that the greatest difference between the measured and computed diameters is not above 6 inches.

The near agreement between the diameters, computed from these two different methods, seemingly so different, appears extraordinary. I found besides, in computing large tables by both of them, that one gave the charge something greater than equal, and afterwards less than the other; but the differences were immaterial.

We have hitherto computed the diameters of mines from their charges; we shall now give some examples to shew how to find the charges, from the given diameters. Thus a mine made in the same soil as the last seven, whose line of least resistance is 10 feet, it is required to find the charge so as to make a diameter of 40 feet: the sum of the squares of the line of least resistance 10, and half the diameter 20, gives 500 for the square of the radius of the globe of compression; and the square root 22.36 of 500, multiplied by 500, gives 11180 for the globe of compression; then the globe of compression 4412 of the second mine, is to the globe of compression 11180, as the charge 160 of the experiment mine is to the charge required, which will be 405lb. nearly.

Let a mine whose line of least resistance is 10 feet be loaded with 170lb. of powder, and have a diameter of 20 feet; it is proposed to make another in the same soil, whose line of least resistance is 15 feet, and its diameter

70, to find its charge. The square 1225 of half the diameter 70, added to the square 225 of the line of least resistance 10, gives 1450, whose root is 38 nearly; and 1450, multiplied by 38, gives 55100 for the globe of compression, and as the globe of compression of the experiment mine has been found above to be 2828, we have $2828 : 55100 :: 170 : 3312\text{lb.}$ of powder for the charge required.

M. Belidor says, to shew the application of the globe of compression in the defence of places, I shall explain the planes and profils of countermines made at la Fere, to blow up the besiegers cannons, and throw them into the ditch, together with another experiment, which threw the cannons into the fortification.

It is well known, that when once the besiegers have established their batteries near the covered way, to make a breach in an outwork, or the body of the place, they become practicable in 2 or 3 days, then the besieged are obliged to surrender; so that the only resource remaining to them, is to retard the finishing these batteries as much as possible, by all the stratagems that can be imagined; but nothing disconcerts the besiegers so much as the destroying them by countermines, and to throw the cannons into the possession of the besieged.

Every time that batteries have been destroyed by countermines, the cannons have been thrown into the trenches, because the resistance is greater on the side of the parapet than on any other; but when the same ground is blown up several times, the chambers may be so disposed, that when the besiegers have re-established their batteries for the second or third time, the cannons may be blown towards the place; because the earth to fill up the excavation having much less tenacity than the former, that side which was the strongest becomes the weakest.

By following this method, I have in 1724 constructed countermines under the glacis of the polygon at la Fere, to blow up the batteries supposed to be erected by the besiegers three times.

Plate I. Fig. 2, 3, 4. The first chamber C, blew up two 24 pounders towards the trenches as usual: the batteries being re-established, the chamber D threw the cannons into the ditch: the batteries being re-established again, the chamber E threw the cannons again into the ditch, to the great surprise of the spectators, especially to some of the miners, who expected quite the contrary. For it was the first time that this method had been practised except at the siege of Turin in 1706, where by chance one of our pieces was thrown into the covert-way, which the besieged carried in triumph into the town.

As such an advantage is extremely proper to raise the courage of the garrison, and to discourage the besiegers, by the length of time to re-establish the batteries, we thought we could not shew better our attachment to his majesty's service, than endeavouring to improve this branch of the countermines, in such a manner, that the first mine, called fougasse, having only eight or ten feet of the line of the least resistance, may throw directly the enemy's guns into the ditch of the place, and even into the work, in order to make use of them against him. This method may be used in places which have wet ditches as well as the dry; since by sinking only 3 feet under the level of the covert way, the height of the banquet and parapet give 7 feet more, this makes a sufficient line of least resistance to blow up a battery. If 8 feet can be sunk instead of 3, the battery may be twice blown up, and a third time if 13 or 14 feet can be sunk. The question is then to throw the cannons the first time into the ditch; for after that, there is no doubt but it may be done again as often as the enemy attempts to raise them, and the depth of the ground will allow it.

This project being sent to court, was ordered to be put in practice in 1739; for which reason a battery was raised in all its forms, for two 24 pounders. Under the middle of which a gallery F G, fig. 5, 6, was made from the foot T, of the banquet of 20 feet long, from which 2 branches GH, GI, were made, each of them 7 feet long, to place the chambers A A, whose lines of
least

least resistance was 7 feet only, being under the axle-trees of the pieces; the gallery was continued in a slope, to make from thence 2 other branches K L, K N, in the same manner as the preceding, but lower, to place the chambers B, B, whose line of least resistance was 10 feet, and at the same distance from the former A, taken horizontally, in order to have the right angled isosceles triangle B D C, fig. 5, whose hypotenuse B C, shews the direction of the action of the powder.

The intent of the little chambers A, A, being to overcome the tenacity of the soil, without any other effect, were charged each with 20 pounds of powder only, whereas the others B, B, were each charged with 600 pounds. The length of the leaders were contrived so as the fire being set to it at F, it went to G, and from thence to the chambers A, A, and to the point K at the same time, and to the chambers B, B, in a few seconds afterwards: the first, A, A, having produced a proper effect, the second B, B, met with less resistance towards the wheels of the carriages than towards the trail, raised the pieces to about 40 fathoms, and then threw them 35 fathoms from the battery into the ditch.

The effect of these mines was much greater than expected, even by those who had the most favourable opinions, from the bare exposition of the project: the most expert in mines at la Fere were more sensible than ever of the certainty of the principles established in our theory, and of all the advantages that may be obtained from the globe of compression.

Though the centres of the two chambers were 18 feet from each other, they yet produced but one excavation of an elliptic form, whose greatest diameter was found to be 45 feet, and the least 27; the depth 18, and the bottom well cleared, without hurting the parapet of the covert way. If then 2 mines produced so great an excavation, to what extremity will the besiegers be reduced if a battery of 10 or 12 pieces was blown up: for where will they find earth enough to fill up an excavation of 35 or 40 fathoms in length, 5 in breadth, and 15 feet deep?

What time will be lost in repairing all these damages ; and what destruction there must be amongst the soldiers, from the fire of shells, carcases, and granades, continually thrown into such a confined place!

Experiments made at Bisy in July, 1753,
by order of the French King, together
with their Use in the Attack of Places.

THE intent of these experiments was to render useless the countermines of a besieged town, by bursting the galleries all round, above and below, to a certain distance, or to change these galleries into so many trenches, by which the covert-way may be taken at once with very little trouble. His majesty being informed of these means, ordered that experiments should be made near the castle of Bisy, belonging to the duke of Belleisle. In consequence of which, a detachment of 75 miners, with their officers, was sent there from the artillery school at la Fere. The work begun with what belongs to the globe of compression ; a soil had been pitched upon the most uniform that could be found, which happened to be a hard sand, mixed with gravel ; there were made 4 galleries, A, B, C, D, fig. 7, 3 feet wide, and 6 high, so as to form a rectangle, whose sides answered nearly to the 4 cardinal points : the 2 opposite ones A, B, which faced the north and south, were each 10 fathoms long, and the other 2 C, D, which faced the west and east, 12 fathoms ; they were lined with stones, in order to shew that masonry was rather an advantage than an obstacle to the effect of powder : the bottom of these galleries had a slope of 6 feet 3 inches, and the mean depth was 15 feet under the surface of the ground, which terminated in a descent from south to north, between the interval of the galleries of that name. In that to the east, C, a branch, L K, was made at right angles of 24 feet long, and at K another, K F, at right angle to this, to place a chamber, E, 30 feet distant from the gallery A, 36 from D, and 42 from B.

B. The other galleries were made by means of 2 shafts or pits, M, I, the one M, to the south was 16 feet deep, and the other, I, to the north 20.

When these galleries were finished, the last pit, I, was deepened nine feet more; so that the bottom Y, fig. 8, was 29 feet below the surface of the ground near the chamber. After this a gallery, YX, was made going directly under the chamber E, with a descent of 18 inches, and 5 feet high, by which its top was 14 feet below the centre of the chamber E, the whole supported with strong planks of oak, and still in the same sort of soil as mentioned before, but so hard, that the miners were obliged to use the chissels. Such was the disposition made to what belonged to the globe of compression; whose object was to see whether it would burst all these galleries.

As it does not appear natural, that a mine, whose effect should be on the weakest side, would burst galleries at a distance of 4 times the length of its line of least resistance, it is no wonder that it should have been doubted; though the experiment made at la Fere in 1732, should have been a proof of it, as the fact was established upon the preceding theory, yet the miners were not convinced, pretending that the powder had penetrated between the soft soil and a bed of strong clay, so far as to burst the gallery. It was plain, that by admitting this theory, the old, and all its consequences, must of necessity be rejected. I kept silence upon this article till 1753, when, in a discourse which I had the honour to make to his majesty on the effect of powder in mines and fire-arms, he ordered immediately that I should be furnished with means to make farther experiments, which are those I have now described.

The 18th of June, the count d'Argenson, who arrived the night before at the duke of Belleisle's, at the castle of Bify, with some general officers and other persons of quality, who came there out of curiosity, went early in the morning, to visit all the works of the mines; after this fire was set to the globe of compression, which

had been loaded the night before with 3000 lb. of powder : it raised the earth to about 150 feet high. They then went to see whether it had destroyed the galleries about it, as well as those underneath, and to what distance the globe of compression had acted ; it was found that it formed an excavation perfectly round of 66 feet diameter, and 17 deep.

The east gallery C, lined with masonry, and at 24 feet distant from the chamber, was entirely burst from one end to the other.

The south gallery A, at 30 feet distant from the chamber, was equally burst from one end to the other, except 2 fathoms near the entrance M, at the west.

The west gallery D, of 12 fathoms long, and 36 feet distant from the chamber, was destroyed to the length of 7 fathoms, 3 fathoms were left near its entrance at the north, and 2 fathoms on the other end.

The north gallery B, which was 10 fathoms long, and 42 feet from the chamber, was destroyed all but 2 fathoms at its entrance at the west, so there was 8 fathoms impracticable, which were divided into 2 equal parts by the perpendicular drawn from the centre of the chamber to that gallery.

As that line formed a right-angled triangle, with half the gallery destroyed, whose hypotenuse is 48 feet ; which hypotenuse is the radius of the globe of compression ; this shews that the globe of compression would have destroyed a gallery at that distance, and consequently quadruple the line of least resistance.

The gallery Y, Z, S, fig. 8, which passed under the chamber E, whose top was 14 feet from it, and length 69 feet, could not be entered farther than the length Y Z of 24 feet, so that 45 feet of it was destroyed ; as the extremity of this gallery was 9 feet beyond the centre of the chamber, it appears that there remains 60 feet from the middle to the entrance, and as there were 24 feet not destroyed, there remained 36 destroyed on that side, which taking for the base of a right-angled triangle Z S E, and the perpendicular E S being 14 feet, the

the hypotenuse E Z, is found to be 38 feet, which therefore is the radius of the globe of compression: so that it would have destroyed a gallery whose top had been at that distance under the mine, consequently 50 feet under the surface of the ground, which is the greatest distance that a gallery can ever be made. These are facts yet extant, and which may be verified upon the spot.

From hence it follows, that if the line of least resistance had been 15 or 16 feet instead of 12, the globe of compression would have destroyed a gallery at 60 feet distant from the centre of the chamber; consequently if the chamber was placed at that depth, and nearly in the middle between two lifting galleries, whose distance is generally from 15 to 24 fathoms, it would have bursted both the envelope and all those under and above them, by increasing only the quantity of powder in proportion. This proves the great use that may be made of the globe of compression, in the attack of a place countermined.

It has been found, that to make use of the globe of compression in a common soil, the chamber should be made upon the same level with the galleries, and its greatest distance be about quadruple its depth nearly; then the diameter of the excavation will be about sextuple that line. And to find the charge, *multiply 3 times the line of least resistance, expressed in feet by 100, and the product will give the number of pounds of powder for the charge required.* For example, having 2 or 3 contiguous galleries, 15 feet deep, at a distance not exceeding 60 feet; make a shaft in the most convenient place, and from thence carry a branch to establish the chamber: then 3 times 15, the depth of the mine, multiplied by 100, gives 4500 lb. for the charge of this mine. From this rule it appears, that the true charge of the globe of compression at Bisy should have been 3600 lb. for a line of least resistance of 12 feet, then the diameter of the excavation would have been 72 feet instead of 66, and in that case the west gallery would have been destroyed to the

the quadruple of the line of least resistance, as already mentioned. The reason for charging the mine of Bisy with 3000 lb. only, was to prevent some houses near it, from being damaged. This rule for charging mines is not founded on any exact theory, but is sufficiently exact, because it is better in this case, to make the charge greater than less.

While part of the miners detachment was occupied in what belonged to the globe of compression, the other was at work to construct a place of arms of a covert-way to countermine it; in order to change them afterwards into trenches of a siege, and to furnish means of a new kind of experiments. This place of arms traced such as one in a real fortification was found to be in a most ungrateful soil, for the bottom was of a very hard free stone, that could not be penetrated without blowing it up; and it was covered with a strong clay, which appeared to be against the intended experiments; but as it would have been looked upon to favour the experiments, by changing the situation, it was thought proper to continue the work in that soil which had been pitched upon by chance, so that if they succeeded in this, there would be no doubt of their success in any other.

Plate II. Fig. 12. At the depth of 12, 13, 14, and 15 feet, were made a gallery *magistrate* 1, 2, 3; an *envelope* 4, 7, at the foot of the glacis; 2 traversing, 1, 4 and 3, 7; and 2 *listner*, 5, 8 and 6, 9; all being 5 feet high, and 3 broad. This work being finished, a sap, B C, was made in the usual form, which crossing one of the listners, and within about 4 fathoms of the other, as happened by chance. The 16th, the besieged miners intending to destroy this head of the sap, set fire to the mines A, B, carried from the listner at the right. The second mine B, which was 10 feet deep, formed an excavation of 27 feet diameter, in which the miners entered to discover the gallery, cleared it, and from thence entered into the listner, which was done in 5 hours.

The 17th, the besiegers intending to destroy, at the same time, and by the same fire, the listner of 20 fathoms, the envelope of 24, and 12 of the traversing; in order to which, they begun at the right to place sand bags before them serving as a retrenchment, then placed the leaders and put ten barrels of powder in two heaps at the end of the traversing gallery; 16 in 4 heaps into the envelope, and as much into the listner; and stopped up the entrance at the excavation: all this work was finished in 7 hours.

The count d'Argenson being arrived, the besieged miners set fire to the mine C, at the left, which they had loaded with 200 lb. of powder, in order to destroy the sap on that side. The besiegers miners entered into the excavation, to discover the gallery; in the mean time the besieged sent 2 miners, followed by lord Melford, out of curiosity, to observe the besiegers, who being arrived at the envelope, the smoke of the leader was so great, that they could proceed no further; then retired in haste into the fresh air, to recover from the suffocation they were affected with in the attempt.

An hour after, the same lord, with a serjeant and a corporal, entered a second time into the gallery, to see whether they could advance farther, but found the stench of the powder still worse than the first time; for attempting to go into the listner, they swooned away, and would have died, had they not been carried out directly, especially the corporal, who did not recover in 24 hours. This example shews, that the miners have not a more cruel enemy than the confined smoke of powder; for if they are in it during a few minutes, faint away, and die if not properly secured.

After this event, fire was set to the leader on the right, which suddenly raised the upper part of the listner, the envelope and part of the traversing, and changed them into trenches, as in fig. 13. to the length of 56 fathoms, being about 24 feet broad, and about 8 deep; a little
after

after were sprung by the same fire, the rest of the communication or traversing adjacent, with half the magistral in the gorge of the place of arms, by means of 24 barrels of powder placed in six heaps, which changed these galleries also into trenches, the length of 38 fathoms, that is, the listner on the right, the envelope, the traversing, and the magistral, formed one continued trench.

The same day the miners, after having cleared the bottom of the excavation near the listner at the left, opened the gallery and penetrated into the listner, charged it and the traversing with 20 barrels of powder placed in 4 heaps; they charged likewise the other half of the magistral gallery, in the place of arms, with 12 barrels of powder placed in 3 heaps.

Things thus disposed, the count d'Argenson and the duke of Belleisle came the 19th, to see the remainder of the operations; the first changed the listner, which was 22 fathoms long, into a trench with more success than the former, as being better cleared; after this, the rest of the magistral gallery was sprung, which made a trench of 20 fathoms. These trenches may be traversed and finished, as in fig 14.

It may perhaps be said, that as these countermines were not defended, it is no wonder that these trenches were so easily made: but this objection deserves no answer; it is sufficient, that the operations made here are what is daily practised at the school of artillery, without any body receiving the least harm.

All these experiments being finished to the satisfaction of the count d'Argenson, without any accident, that minister, to verify them to the king, had a memorial drawn up, and signed by Messrs. Valiere, Gourdon, lieutenant generals; d'Auville, Chateaufier, Gribauval, captains of miners; Belcourt, third commander of the school of artillery at la Fere and Belidor.

It is after this memorial that the preceding facts have been written, which cannot be suspected of any alterations,

tions, every thing was approved of by all who were invited by M. Count d'Argenson, to see them.

From these experiments has been deduced a method for changing galleries of mines into trenches, viz. after having stopt the entrance with sand bags or wood, the heaps of barrels of powder should be placed at equal distances from each other, to make them take fire together, and this distance should not exceed triple the depth of the gallery, from thence the length of the leaders will be determined. The charge should not be too great, to prevent the making too deep a trench, for the soldiers to defend them; each heap of powder should contain as many barrels of 100 lb. as there are feet in the fourth part of the depth of the gallery, in a common soil. For example, having a gallery of about 24 fathoms, and 16 feet deep, there should be 4 barrels in a heap, and 4 heaps, distant 6 fathoms from the centre of the one to the centre of the next, and half that distance from the ends. This may be done in 4 hours. If the galleries were situated in a different soil, than that we have here supposed, a trial must be made to determine from thence the proper charge.

To account for the effect of powder in galleries of mines changed into trenches; I consider that these galleries are in the same case as a musket that is to be burst, which requires not to be charged with a great quantity of powder. For if its end be well stopped, when the powder is fired, the flame being prevented from rushing out, endeavours to extend itself, till a sufficient quantity is fired to overcome the obstacle that resists it, opens the barrel from one end to the other. The same thing happens in galleries of mines; for when the heaps of powder are properly disposed, and the leaders so contrived as the several heaps take fire at the same time, the flame extends all over till a sufficient quantity is lighted to burst the gallery. From hence it follows,

1. That the method of changing galleries of mines into trenches, will be of excellent use, especially when the soil is gravel or stony, which is improper to proceed

ceed by sap; for this is no hindrance to the effect of powder, as found by the experiments made at Bisy.

2. That the countermines, as commonly made in a fortified place, are a disadvantage to the besieged instead of an advantage; especially, if the besiegers have plans and profiles of them, because they cannot spring an advanced mine, without giving the enemy an opportunity to burst their galleries, and advance to the covert-way with very little trouble, and to erect batteries with security.

3. Henceforward, the chance of the besieged and besiegers will entirely be changed, since the latter will find dispositions ready prepared, which will turn more to his advantage, than the place could formerly have received from them.

4. That in the attack of places countermined, the besiegers miners will be of much greater importance than ever; since the taking the covert-way will be their lot, as well as all those works which have under-ground communications with the place, such as the citadel of Tournay and many others, and the place itself, if it has any such passages.

5. That the present method of making countermines, leading towards the covert-way, must necessarily be changed, in order to prevent the enemy from turning the galleries to his advantage.

Plate III. Fig. 17. To apply our method of attacking the countermines in a place besieged, I supposed, the first and second parallels made the latter A, B, C, to be distant of about 60 fathoms from the pallisades of the covert-way, and from thence the trenches are carried on in the capital of the ravelin, and in those of the adjacent bastions of the front attacked; and after this, batteries L are made of cannons and mortars to enfilade by ricochet, the covert-way, and the ramparts parallel to it, to destroy their defences. During this time, the sappers carry on the saps towards the places of arms in the covert way, both saliant and retring; to establish the heads E F near the ends of the listners G, G, before the

the saliant angles, and the miners proceed under-ground to place chambers I, overcharged, between the extremities of the listners of the re-entring angles: I suppose they have taken the precaution to sink their shafts as deep as the countermines, that the chambers may nearly be upon a level with the galleries, and that the shafts are placed in the trenches K, which lead from one battery to the other, not to interfere with any other works; from the bottom of these shafts they make the galleries K L of about 20 fathoms long. This will be a work of 4 or 5 days to the establishing their chambers, which should be finished at the same time, that they may be sprung together; the sapers will by this time be arrived to the heads E F, to induce the besieged to spring some of their mines, to destroy them; with a little attention his intention may be discovered time enough to withdraw the troops.

Supposing, that they have sprung 2 or 3 mines at each side, as soon as this is done, the miners enter into the excavations to discover the galleries, which they must do at the same time, while the sapers form a lodgment in the excavation. When the galleries are found and cleared, they stop up their entrances, to keep in the smoke till they want to make use of them. On the other hand, all the globes of compression are fired, and from their excavations search is made on the right and left to discover the listners; so that, if the measures have been rightly taken, 14 entrances into the countermines will be found, by which it will be out of the besieged's power to resist equally every where; should there be but half that number practicable, it would be sufficient to get possession of all their mines; of which, only those that are convenient to advance the siege, are to be changed into trenches.

Observations on the preceding Theory.

That this theory grounded on the globe of compression, is a great improvement upon the art of mining,
must

must be allowed: the experiments made at Bisy and la Fere, before many military gentlemen, demonstrate its great effects, and intirely overset that old erroneous opinion, hitherto believed by miners in general, that powder confined in mines acts on the weakest side, and not downwards nor side-ways. Since galleries were destroyed under and at the sides of the chamber, at the distance equal to four times the line of least resistance; whereas before it was supposed that it could not make the diameter of the excavation above twice that line. Therefore, as long as this erroneous opinion, insisted upon by all authors, subsisted, the theory of mines could not be brought to any degree of perfection.

The method of throwing the cannons of batteries placed on the covert-way, into the ditch, is no less important, since nothing can dishearten the besiegers so much, as to see their batteries for making a breach destroyed as oft as they attempt to raise or repair them. It may be observed that the small mines A, Plate I. fig. 6. seem not to be absolutely necessary, provided the great ones B, are placed directly under the breech of the gun; for in this case, as the part of the gun and carriage towards the place is much heavier than the other, if the mine be properly charged, must throw the guns towards the ditch, without the help of these small mines; for this has been effected by one mine only, at Byfleet camp, some years ago, by Matthew Clark, one of the greatest engineers of his time.

The greatest advantage of this theory consists in changing the galleries of countermines into trenches of an attack; since it reduces the most dangerous and difficult part of a siege, which is that from the third parallel to the intire possession of the covert-way, into a very short and safe method, supposing the place countermined. This method is however liable to some objections: M. Belidor mentions one; which is, *that it may be said, the countermines in the place of arms not having been defended, it is not to be wondered that such an advantage has been made of them:* without any other answer than
what

what is daily practised at la Fere. Now if the besieged are prevented by the smoke to enter into the galleries, does not the same difficulty obstruct the besiegers? It is true, he says afterwards, that the entrance from the excavation is kept stopped till they want to use them, and when opened, the air enters at one end and drives out the smoke through the other. But then so soon as the gallery is cleared from the smoke, it may be entered at both ends, by which the besieged can with an equal advantage defend them, as the besiegers to get possession. And if the besieged are aware of the enemies design, they may stop the entrance on their side, by which it will be impossible for them to make use of them against the place. It is true that the besieged deprive themselves of the use of the rest of their countermines, unless they are loaded and stopped beforehand, which is not to be done in certain circumstances.

If these stratagems should be foreseen by the besieged and prevented mostly, yet by means of the globe of compression, their galleries may be destroyed so as to be quite useless, the besieged will be enabled to proceed in their trenches, and raise their batteries without any other disturbance but from above-ground. From whence it clearly appears, that the countermines, formerly the greatest obstacle of a siege, are now of very little advantage to a fortified place.

The great effect of powder, though not confined, as hitherto thought necessary, has been known long ago. In the duke of Sully's memoirs, page 136, octavo edit. vol. I. we find this remarkable passage; " the king of Navarre took Monsegur. Captain Milon " inclosed five hundred pounds of powder in a bag, " which he found means to introduce into a drain, from " the town into the ditch between two principal gates " of the town; the end of the leader was hid in the grass. " Every thing being ready to play off this machine, " the king gave us leave to go and see its effect; which " was surprising. For one of the gates was thrown " into the middle of the town, and the other into the

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" field.

“ field, fifty paces from the wall: all the vaults were
“ destroyed, and a passage was made in the wall for
“ 3 men to enter a-breast, by which the town was
“ taken.”

M. Valliere's Dissertation on Mines, and their Advantages in the Defence of Places.

I shall not give, in this dissertation, the construction of mines or countermines, the position of listners, chambers, their charges, nor the manner of using them; but only a general idea of the advantages which may be drawn from countermines, if they were constructed and defended as they should be. To explain every thing, it would be necessary to enter into the particulars of the practice, besides trigonometry; treat of the theory of the collision of bodies; the communication of motion; the resistance of solids on the various forces of percussion, and elasticity of the flame, arising from different quantities of powder on the time; the different manner of its inflammation, in different fire-arms, according as the fire is conveyed; and, in short, into the physico-mathematical knowledge, which requires a chain of demonstrations sufficient to fill a large volume, of which this discourse could only serve as a preface.

When Spain made the conquest of the kingdom of Naples from the French, Francis George, an Italian architect at Naples, proposed to Peter Navarre, the Spanish general, besieging at that time the castle del Ovo, a method of becoming soon master of this castle; the French who defended it, were the first who felt the effect of powder in mines; the architect, whether by knowledge or by chance, placing the powder in such a manner, that he threw the wall and garrison into the sea. This was then the origin of the artificial vulcano, invented to facilitate the taking of places; but it is found on the contrary, that it is more advantageous in the defence, without having as yet been rightly considered.

It

It is known, that the perfection of arts and sciences is reserved to succeeding generations. With respect to the science of mines, judging from what has been practised, there are certain principles, which, according to all appearances, have not as yet been discovered; and from which are deduced such facts and advantageous means for the defence of places, as would be unpardonable in us to have neglected.

What I have seen best on the effect and construction of mines, are memoirs, containing several experiments of mines made since these twenty-five years; giving the charges of mines pretty exactly, and the diameters of the excavations, according to their different lines of least resistance; I say pretty exactly, because there is a certain rule and geometrical accuracy to be observed in these things, not mentioned in those memoirs. For instance, it has been found in practice,* that a less quantity of powder is required, in proportion to the earth, in large mines than in small: the reason given by some is, that a great quantity of powder produces a greater force in proportion than a less: but those that argue in this manner would soon have discovered their error, had they considered, that not only the weight to be raised is to be considered, but likewise the tenacity of the parts; and as the tenacities are proportional to the surfaces, and the weights to the solid formed by the excavation; and the surfaces of large bodies are less in proportion than in small; the charges of large mines should be less in proportion than those in small.

This discourse on the proportion of charges only, shews the necessity of geometry in the use of mines; the bare knowledge of the practice is not sufficient to understand what has here been said: there are besides other cases, wherein it rarely succeeds, though it be sufficient in the

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attack

* All the subsequent argument appears to be without foundation, by all the experiments made at la Fere at different times. For it was found that the charges were always proportional to the quantities of earth blown up, or the globe of compression. M. Valliere has not lessened the charges of large mines in his tables; which also contradict what is here said.

attack of a place not countermined; because when nothing obstructs the miners passage, it is easy to blow up a counterscarp and make a breach in a bastion, and if some mines do not succeed, it is owing to the ignorance, scarcely pardonable, of those who undertake to construct them, unless some unforeseen heterogeneous matter intervenes, and forces the powder to act differently from what it would have done in an uniform soil; but this accident happens oftner through ignorance than anything else, because a skilful miner commonly knows where these inconveniences are to be apprehended, and if he does not know how to remedy them, he should at least give notice to the general.

It has not yet been rightly distinguished, how far the word Countermine agrees to mines prepared for the defence of places; all know how much they intimidate the besiegers, but the harm they have hitherto done is nothing in comparison to what they may do, and what obstruction they may make. I shall not pretend to say, that they may render a place absolutely impregnable, but I do not see how, with equal skill, to overcome all the obstacles, nor to succeed in an attack of a place countermined properly, and skilfully defended.

It is presupposed that I mean the situation of a place proper for mines, well fortified, with a sufficient garrison to defend it, provided with warlike stores, provisions, and every thing else, which experience has shewn to be necessary.

A miner that knows how to use countermines constructed as they should be, may stop the enemy's miners, stifle them, or destroy their works in such a manner, as to make it impossible for others to return to the same place, or, if he please, let them enter the galleries, block up the passage, and take them prisoners, or kill them if thought proper. In short, the besieged who know how to take all advantages, will be master of the fate of their enemies: for without mentioning all the traps and stratagems which the enemies cannot foresee; finding it im-
possible

possible to advance, and the under-ground passages being stopped, and not being able to make mines that can be of any use to them; if necessity obliges him to brave the mines, and to carry on the attack above-ground, he must be very obstinate to persist in spite of all the hardships that the besieged can make him endure, not only in making his approaches, but likewise in making his lodgment on the covert way, and every where else, where he dares to carry on this work.

If he proceeds by sap to the covert-way, it will be proper to give him notice from time to time, by some mines, of the danger he is in; if he makes his attack sword in hand, mines appear then useless; yet they may startle the troops during the attack, and bury some men; but as the excavations may serve for lodgments, it will be better to reserve the mines for disturbing the work, and consequently to gain time; besides, these first mines should not be loaded till they are to be used, in order to be always ready to prevent the enemy from advancing, which cannot be done, if they are charged before. The enemy being arrived to the covert-way, may attempt to re-enter the ground, whilst he compleats his lodgment; but he will again be obstructed, and find on all sides the same difficulties as before. So soon as he begins to raise batteries for making a breach, it will be proper to destroy all the lodgments on the covert-way by the uppermost mines, for very good reasons, and not wait till the cannons are mounted; for these small mines loosen the earth where the cannon are to be, by which the next mines will throw the cannon, when mounted, towards the town. These batteries being repaired, and the cannon mounted, which cannot be done in a short time, the mines, which I suppose properly disposed and charged, will throw the cannon, a second time, into the ditch of the place. Such an adventure must astonish an enemy, for here is another battery and lodgment to be made; and when other mines throw the cannon again into the ditch a third time, if he is bold enough to venture raising batteries again, he will meet with the same reception. In short, when there is a depth of earth

of 25 or 30 feet, it is easy to blow up the same surface near the covert-way, 6 or 7 times, which certainly is more than sufficient to dishearten the most obstinate enemy.

These mines should be disposed in such a manner as not to damage the parapet of the covert-way, that it may remain in a condition to be occupied as oft as the lodgment is demolished; at the same time the saps, communications, and parallels, by which the enemy maintains his lodgment on the covert-way, must not be spared, some mines must continually be sprung, with the precaution to destroy always those works which are found most complete.

It must here be observed, that if the depth of earth near the covert-way admits of being blown up 6 or 7 times, it is easy on a level ground of that depth to dispose the chambers of mines in such a manner, as to blow up the same spot 20 times all over the glacis and beyond it, because they are not confined on one side, as those near the covert way.

If the mines made it impracticable to make a breach with cannons, and yet the enemy is obstinately bent to pursue his enterprize, what measures can he take? Will he have recourse to escalades? This scheme is chimerical, and little to be feared, for a garrison that knows how to defend itself. I mention this, because I happened to be at Landau when besieged in 1704, where the garrison, brave as it was, having done all that could be expected, were at last in fear of an escalade; on which suspicion, they determined, after 2 days debate, unseasonably to let the water into the ditch. Will the enemy have recourse again to mines? There are but two ways to arrive at the place or outwork; the one, to pass under the ditch from the covert-way; a tedious work, in which he certainly will be obstructed; the other, to throw the counterscarp into the ditch, and to pass it by means of an epaulement. In both ways he may sufficiently be obstructed, to be disheartened. But suppose he arrives to the body of the work, a principal gallery with

with listners, placed behind the scarp, will render his success impossible.

The present practice is, that the enemy advances to the covert-way by means of covert-saps, that is, by underground galleries, leaving only half, or a foot of earth over their heads; then throwing down this head, their lodgments are almost quite finished. Nothing is more easy than to stop this work, and to oblige the enemy to proceed in another manner, if thought proper.

From these general hints of countermines it appears what may done, when joined to a proper conduct of the garrison, which may and should, by a well-regulated conduct, contribute to the entire destruction of the enemy, in taking advantage of all the disorders he is put in, by the effects of countermines. It must be confessed, that this is the best, and perhaps the only defence, from which such great advantages can be made.

As we have not as yet heard or seen a defence of this nature, what I have said in favour of countermines, may perhaps appear a mere imagination; yet I advance nothing but what is grounded on theory and confirmed by experience; it is matter of fact, and I not only can assert the possibility, but likewise the easiness of its execution.

No countermines I have seen, in the several attacks I have been at, were disposed in a proper manner, nor all the advantage made of them, if properly exerted. It is true, that these advantages depend on such mechanical principles as are taught by geometry, which few miners are acquainted with.

I must own, that 15 or 20 miners commonly sent into a place besieged are by no means sufficient; for the most that they can do, is to make a few mines here and there under the glacis, which only frightens the enemy without doing any great harm; the little time that is gained by them is not worth mentioning. Besides, for want of communications, the mines must be charged at the approach of the enemy to the covert-way, which is a great disadvantage; to this I may add, that if the num-

ber of miners were greater, if their works are not begun before the siege, the situations are oft such, that very little resource can be expected from them.

To prepare such countermines as I propose, requires time and expence, but neither are so considerable as might be imagined: in 3 or 4 months, if no rock intervenes, a place may be sufficiently countermined, as far as 60 or 70 fathom from the covert-way, supposing a sufficient number of workmen. As to the expence, it is a mere trifle, in comparison to the many millions of livres the fortification of a place costs, to preserve which requires all the care and precaution that is possible; for in a front of a polygon of 200 fathoms, I suppose requires 2000 fathoms of galleries, which may perhaps cost 35000 livres in materials and workmanship, and 100,000 lb. of powder in reserve for that use.

It must be observed, that if such a work be undertaken, it should be carried on with all speed, and without intermission; all the parts of a place, susceptible of making mines, should be finished together, for it would be dangerous to be attacked in a front not prepared, whilst all the others are; it will besides instruct the enemy of your condition, which he always discovers too soon.

The science of countermines has a superiority over that of fortification, because the latter is partly arbitrary, whereas the former is determined by the situation of the works and nature of the soil: another advantage the mines have, no less considerable than the former, is, that the position of these mines may be so varied, as to be impossible for the most experienced enemy to gain any intelligence of them.

The galleries supported with wood, are easier defended, and more commodious to avoid certain accidents, than those made of masonry; but as wood decays, it is more convenient to make those galleries, which are to stand a considerable time, with masonry, by observing however to make the roof flat, instead of round as they are commonly made, to prevent certain accidents. As to the objections which may be made against this method of making

making countermines; the most material is, that the miners cannot enter those galleries filled with smoke arising from the springing of a former mine, which suffocates them; but these, and other inconveniences, may be avoided, by a particular construction of these galleries, which purifies the air, and makes it circulate*.

General Construction of the several Stages of Countermines.

Fig. 18, in the line gH , representing the slope of the glaciis, take the line gF , equal to 4, 5, or 6 feet, for the thickness of earth to be left to serve as a parapet to the covert-way: take Fz , equal to half the diameter of the excavation, and zO , the perpendicular to FH to the line of least resistance; then the line FL will represent the section of the plane in which the several stages of countermines are placed. In order to find the distances of the chambers in that plane, take OM , ML , each equal to FO , and the points O , M , L , will represent the centers of the chambers: this may be carried on to any depth. This construction is evident from M. Belidor's principles, that the charges of mines are proportional to the cubes of the radii or lines OF , MO , LM , of the globe of compression.

M. Valliere will have the line MO always equal to the line of least resistance, Oz , of the mine next above it; but observes, that in a soil of an uniform density, experience shews that these lines are to be increased by one third of the line of least resistance; so that if the line

* What this particular construction of galleries, which M. Valliere mentions here, is, remains as yet a secret; nor can it be guess'd at: for if he means that air-holes may be made from distance to distance, they may be discovered from above, and either stopped, or some stinking composition thrown through them into the galleries, and thereby increase instead of diminishing the danger: or whether, the galleries, by having several entrances, and a communication with one another, can be freed by this means from the sulphurous smoke, soon enough to be entered and defended when required, can, in my opinion, only be known from experience.

line of least resistance Oz is 12 feet, OM should be 16; which answers our construction nearly. He supposes likewise in his construction, that the diameter of the excavation is always double the line of least resistance; but we have proved, that it may be triple or quadruple of that line. It is therefore necessary in this construction to determine the ratio of the lines Fz and zO , from the charge, to determine the plane FL of the several stages of mines.

Fig. 19. shews the disposition of the chambers of the countermines, in a section of the glacis parallel to the covert-way; and how they should be placed under each other.

Explanations of the Figures.

P L A T E I.

- Fig. 1. Shews the figure of an excavation.
 Fig. 2. Shews how the same battery has been blown up 3 times by 3 mines C, D, E , placed below each other.
 Fig. 3. Shews the plan of the galleries and chambers.
 Fig. 4. Profil of the same mines lengthways of the battery.
 Fig. 5. Shews how a battery is blown up once only.
 Fig. 6. The plan of the galleries of the preceding mines.
 Fig. 7. Plan of mines constructed at Bisy, to shew the effect of the globe of compression.
 E. Chamber, whose line of least resistance was 12 feet, and loaded with 3000 lb. of powder.
 I F. Gallery 69 feet long, going from the bottom of the pit I, and passing 14 feet under the chamber E.
 H G. Branch from the gallery, 14 feet lower, and 8 distant from the chamber E.
 Fig. 8. Section thro' BA , passing thro' the chamber E.
 YZX. The gallery going from the pit I, sloping 18 inches from Y to Z , the rest being level.
 V. T. Horizontal line, and ON the slope of the ground of 5 feet from the gallery A to the gallery B.
 R S. A perpendicular of 26 feet.
 Fig. 9. Section thro' DC of the plan passing likewise thro' the chamber E, and the galleries D, C .

P L A T E II.

Fig. 10. 11. Shewing the extent of the excavation made by the chamber E, fig. 7, and the parts burst of the high and low galleries.

Fig. 12. The plan of a place of arms D in a covert-way, countermined.

Fig. 13. The same place of arms, as appeared when the galleries were blown up, to make trenches.

Fig. 14. The same as the two former, only cleared and traversed, to prevent being enfiladed.

Fig. { 15. } A section of the 13th figure.

Fig. { 16. } A section through the 14th figure, formed into steps.

P L A T E III.

Fig. 17. Shews the plan of an attack of a place countermined. The great circles, I, represent the effects of the globes of compression; and the little circles the countermines sprung by the besieged to blow up the advanced saps of the besiegers.

F I N I S.

A Scheme to improve Artillery,

For SEA and LAND SERVICE.

THE indispensable necessity of having a very large Artillery, for Sea and Land Service, and the extraordinary expence attending it, induces me to hope that this proposal for reducing the weight and expences, may be acceptable; especially as no nation have as yet made any such attempt.

This is to be considered under two heads: the one to diminish the weights; and the other not to use any brass field artillery, but only iron; to lessen the great burthen of our ships of war, and to carry larger calibers than those of other nations of the same rate. If the weights of our guns are diminished, they will require fewer hands to manage them, and of consequence, a smaller number will be exposed to danger at a time: and if we carry larger calibers, our rates will be a match for larger ships.

The advantage of using iron guns in the field instead of brass, will be that the expences are lessened in proportion to the cost of brass to that of iron, which is as 8 to 1.

The only objection against iron is, its pretended brittleness: but as we abound in iron, that is stronger and tougher than any brass, this objection is invalid. This I can assert: having seen some that cannot be broke by any force, and will flatten like hammer'd iron: if then we use such iron, there can be no danger of the guns bursting in the most severe action.

Though brass guns are not liable to burst, yet they are sooner rendered unserviceable in action than iron. For by the softness of the metal, the vent widens so soon, and they are liable to bend at the muzzle, that it would be dangerous to fire them; as we have found by experience at Belleisle, and where we have been obliged to take guns from the ships to finish the siege.

These being undeniable facts, no possible reason can be assigned against using iron guns in both sea and land service, and thereby lessen the expences of artillery, so considerably as will appear by the following tables.

Length

Length and Weights of Iron Ship Guns.

OLD PIECES.

NEW PIECES.

Calib.	Length	Weight	Calib.	Length	Weight
	Ft. In.			Ft. In.	
3	4 6	7 1 7	3	3 6	3 3 0
4	6 0	12 2 13	6	4 4	7 2 0
6	7 0	17 1 14	9	5 0	11 1 0
9	7 0	23 2 2	12	5 6	15 0 0
12	9 0	32 3 3	18	6 4	22 2 0
18	9 0	41 1 8	24	7 0	30 0 0
24	9 0	48 0 0	32	7 6	40 0 0
32	9 6	53 3 23	42	8 4	52 2 0
42	10 0	55 1 12	48	8 6	60 0 0

Guns of this construction appear sufficiently strong from the proof of two three-pounders, made for Lord Egmont, and that they may even be made lighter and of equal service.

Length and Weight of Battering Pieces.

OLD BRASS.

NEW IRON.

Calib.	Length	Weight.	Calib.	Length	Weight.
	Ft. In.			Ft. In.	
6	8 0	19 0 0	6	6 1	9 1 0
9	9 0	25 0 0	9	7 0	14 0 0
12	9 0	29 0 0	12	7 8	18 0 0
18	9 6	48 0 0	18	9 0	29 1 0
24	9 6	51 0 0	24	9 8	37 3 0
32	10 0	55 2 0	32	9	42 0 0

Total 227

Total 151 0

Diff. 76 2 0

That

That these guns are sufficiently strong, is evident from the former trial; besides, there are several 32 pounders of the same dimensions and weight now existing and serviceable, though cast in King Charles the Second's time.

N. B. These battering pieces may serve in Garrisons.

It appears from these tables that no proportion has been observed in any guns hitherto made, in respect to their length or weight, but merely by guess.

Some examples to shew what may be saved by this scheme.

The Royal George carries a hundred brass guns, which weigh together 218.2 tons, the ton cost 130 pounds, workmanship included.

The expence of these guns is then - - 28366 pounds

A set of the iron guns of the same number and calibers, according to my construction, weighs } 127.8 tons

The ton cost 16 pounds, and the whole set } 2044.8 pounds

The Royal George carries then 90.4 tons more than is necessary, and the difference between the expence is } 26321.2 pounds

That is 12.5 times more than the new iron set costs: or twelve ships of the same rate may be fitted out less charge.

A set of the { Old } irons guns for a { 204.4 } tons
 { New } first-rate weighs { 127.8 }

The difference between the weights of the old and new is } 76.6 tons

The difference between the expence is then } 1225.6 pounds

A set of brass battering pieces weighs 11.36 tons

A ton cost 130 pounds, and the set 1476.8 pounds

A set of the new weighs - - - - - 7.55 tons

The ton costs 16 pounds, and the set 117.8 pounds

That is 11 times, and 632 over, more than the new set, or eleven sets of the new, could be made at less expence than one of the old.

The

A R T I L L E R Y.

191

This table shews what may be saved in the Navy; and if we add those on board floops, the different garri- sons, and the field train, with the great expence of their carriage in the field, it may be found pretty near as much more.

Numb. of Guns.	Weight of Old.		Weight of New.		Differ.		No. f Ships.	Total Difference	
100	4367	3	2556	0	1811	3	5	9058	0
90	3537	3	2001	0	1536	3	9	13827	3
80	3108	3	1827	0	1287	3	7	9014	1
74	3091	0	1840	2	1250	2	32	40016	0
70	2997	0	1796	2	1200	2	10	12005	0
64	2543	3	1305	0	1258	2	23	28485	2
60	2177	3	1185	0	972	3	30	29782	2
50	1881	1	1035	0	846	1	19	16078	3
44	1365	2	705	0	660	2	8	5284	0
40	1234	2	312	2	922	0	9	8298	0
36	963	3	450	0	513	3	7	3596	1
32	956	2	435	0	521	2	28	14602	0
28	593	2	285	0	308	2	23	7095	1
24	531	3	255	0	276	3	12	3321	0
20	421	2	191	1	230	1	15	3453	3

Difference between the Weights - - - - - 203918 3 0

Expences of the	{	Brass guns of two first rates,	—	203918	15	0
	{	Iron ditto	— — —	53109	5	0
We get				£.	257028	0 0

If then no material objection can be made to this proposal, so beneficial to the nation, I humbly hope that it will be put in practice, and that my trouble of composing it, after above fifty years application, to theory and practice, will be considered.

JOHN MULLER.

Proportion of Ammunition for the following Troops, being the Extra Allowance for one Year, commencing the 25th of March, agreeable to King's Warrant, 1760.

	Ball.			Flints.		
	Musq.	Carbine.	Pistol.	Musq.	Carbine.	Pistol.
A Regiment of Foot of 900 Men for -	35			2700		
{ Service						
{ Exercise	11			1800		
A Regiment of Dragons of 360 Men for	9		2	1134		2268
{ Service						
{ Exercise	1			756		1512
A Light Troop of 121 Men for - - -	2½	7		363	242	393
{ Service						
{ Exercise						
	11½					262

N. B. The

N. B. The proportion of ammunition for a regiment of foot is 64 rounds for each man for service, at 6 drachms each cartridge, and 135 rounds each man for exercise, at $\frac{1}{4}$ of an oz.

Musquet flints, 3 to each man for service, and 2 for exercise.

Musquet balls, 20 to each man for exercise.

The proportion for a regiment of dragoons is one pound of powder for service, and two pounds for exercise to each man ; each cartridge to contain the same as those of the foot.

The proportion for the light dragoons is 64 rounds for each man for service, at $\frac{1}{4}$ of an oz. each cartridge, and 405 rounds each man for exercise, at 3 drachms each cartridge.

The battalions of militia embodied are to have the same proportion of ammunition as a regiment of foot, according to their numbers.

Office of Ordnance, May 14, 1760.

Form of a Certificate for Ammunition to be addressed to the Right Hon. and Hon. the BOARD OF ORDNANCE, whenever a Supply of Ammunition is wanted.

THESE are to certify the Right Honourable and Honourable the BOARD OF ORDNANCE, that the last Supply of Ammunition received for Use of Regiment of or Company of under the Command of is nearly expended in the Duty and Exercise of the said Witness my Hand this Day of

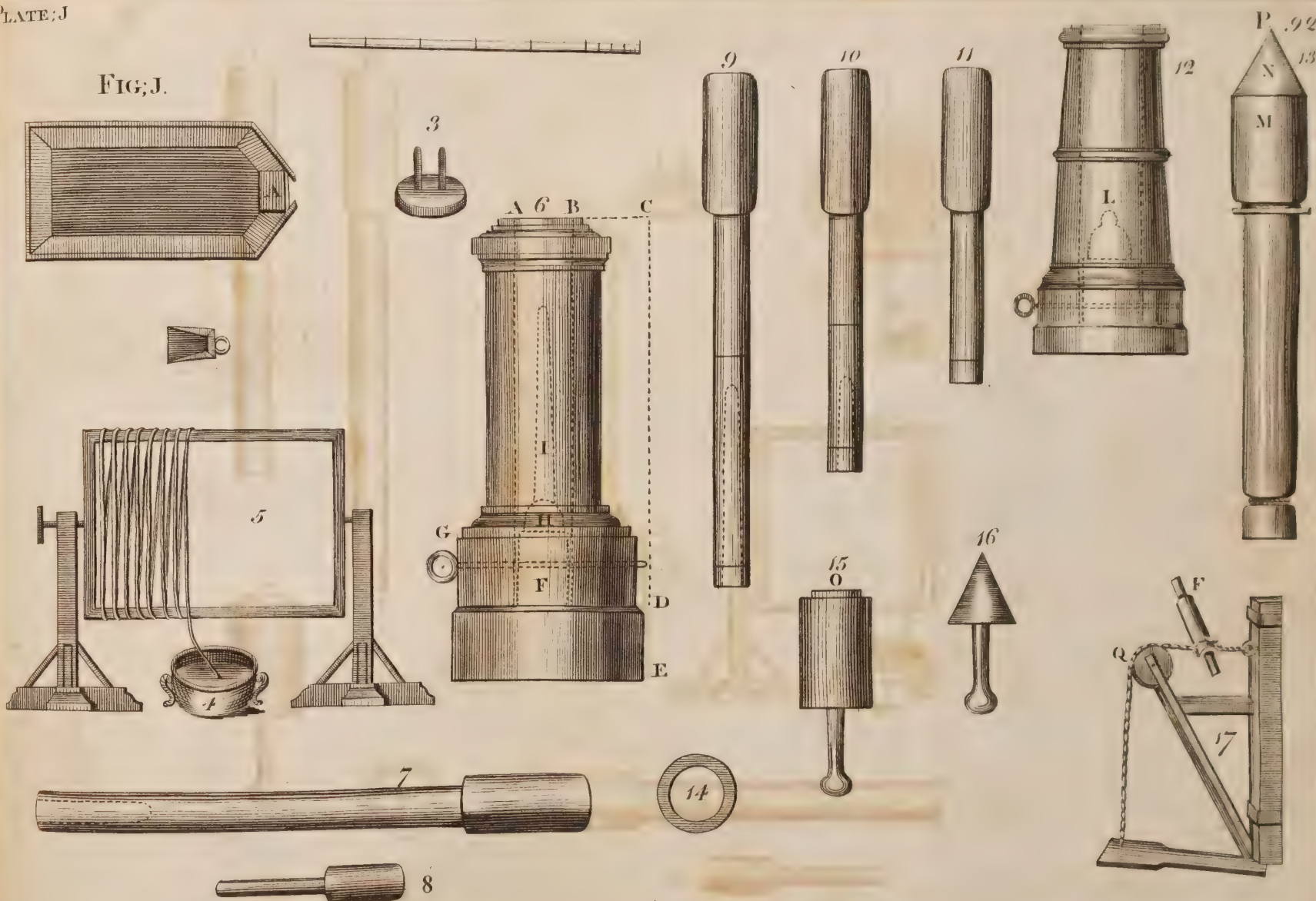
To the Rt. Hon. and Hon. the Board of Ordnance.

F I N I S.

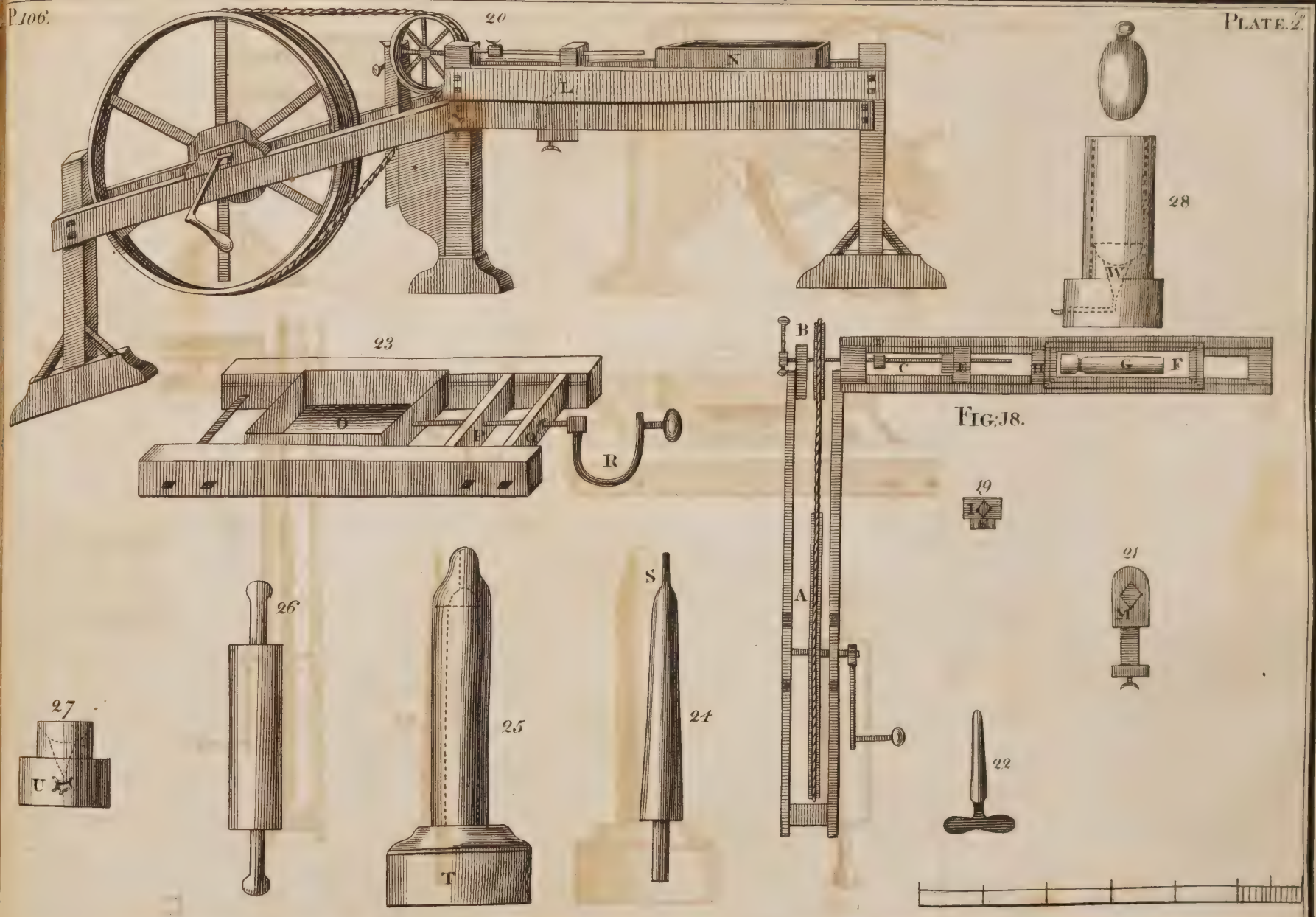
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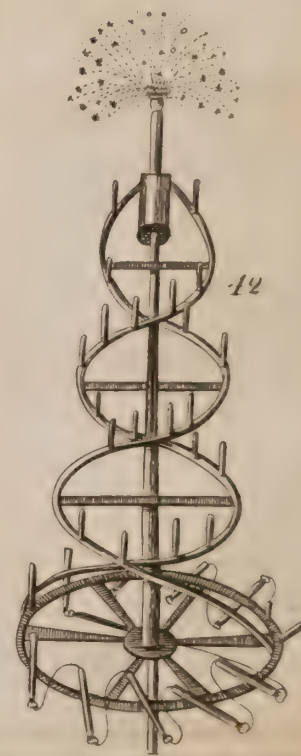
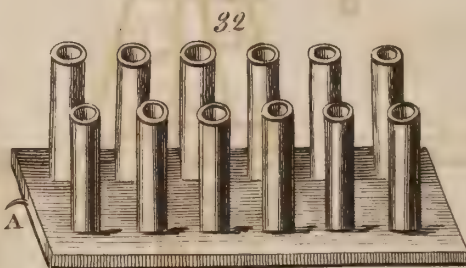
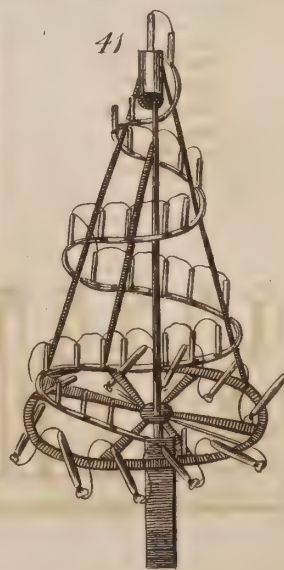
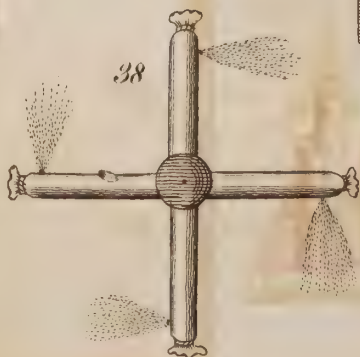
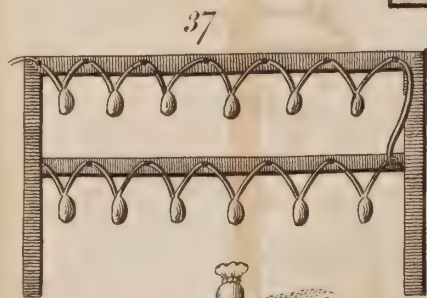
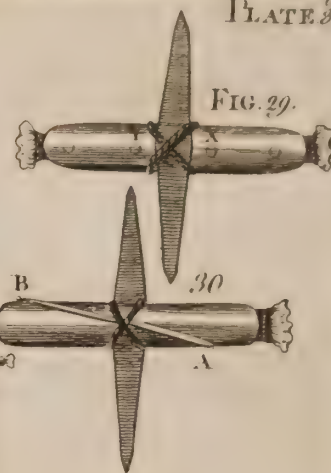
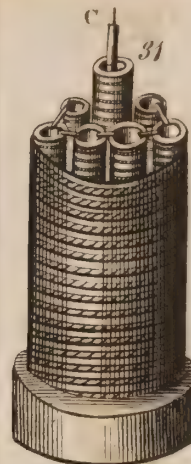
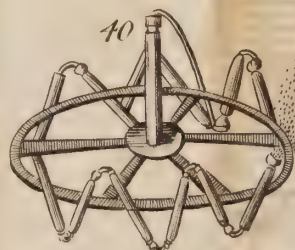
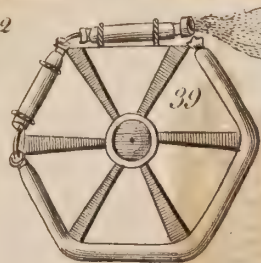
FIG. J.













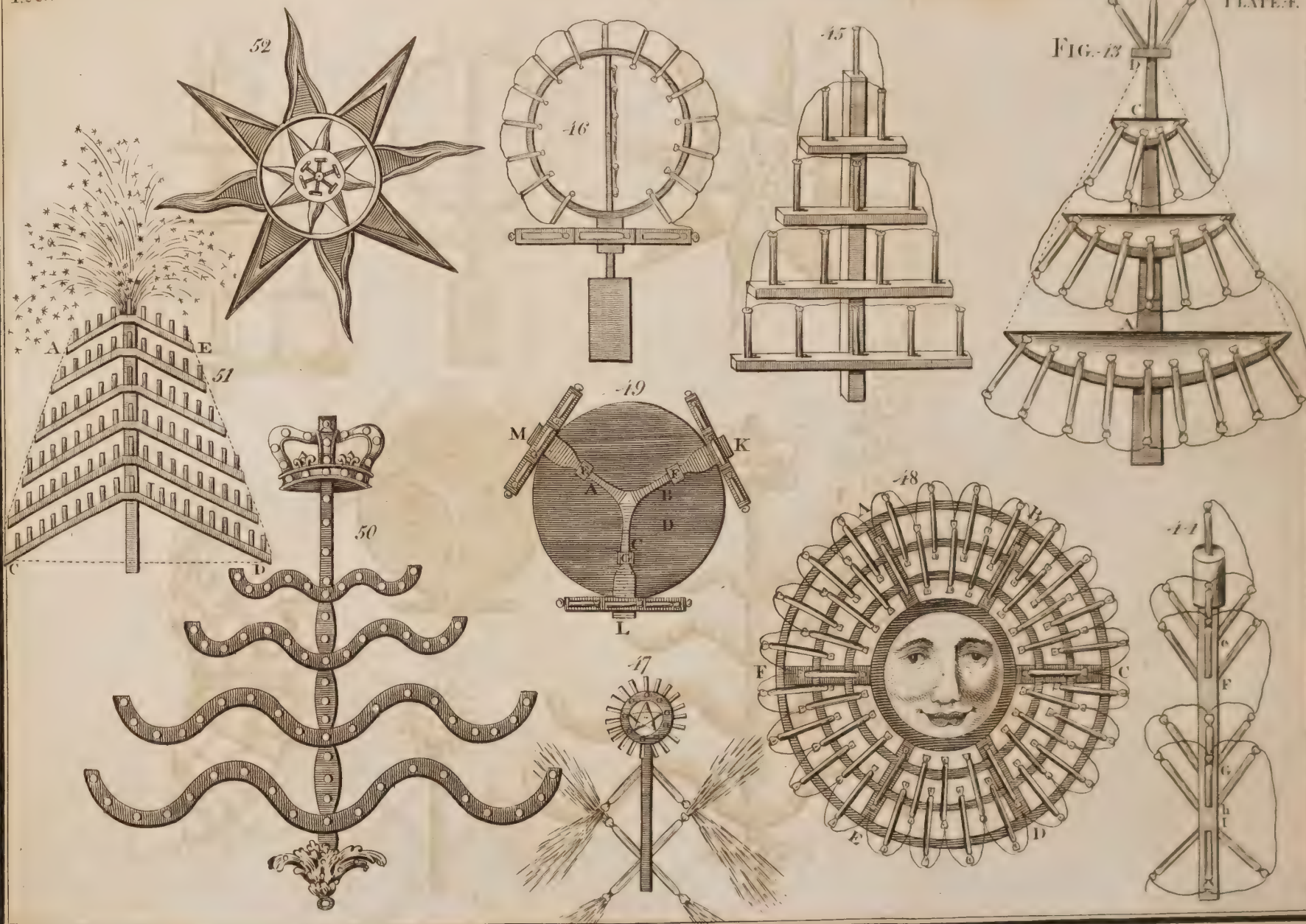




FIG. 54

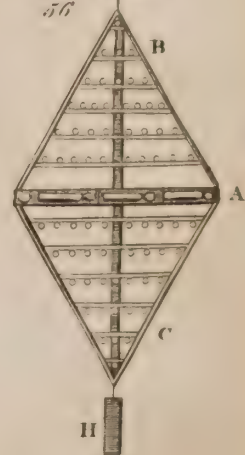
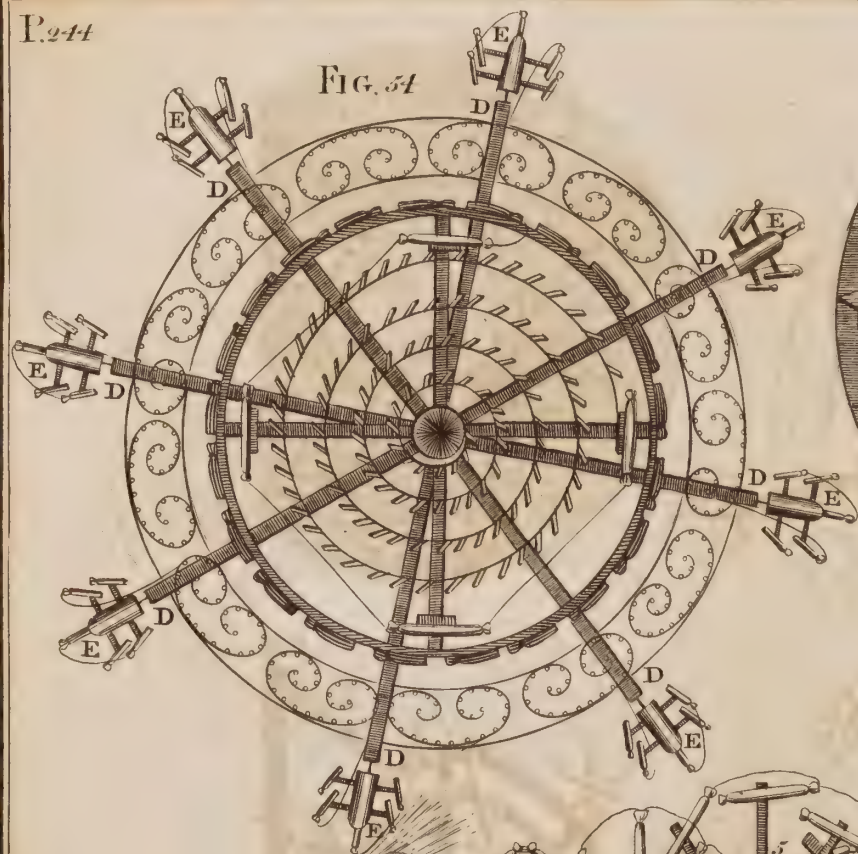
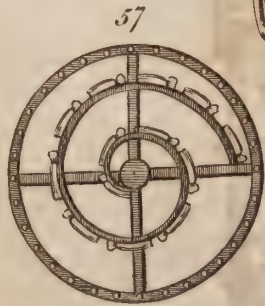
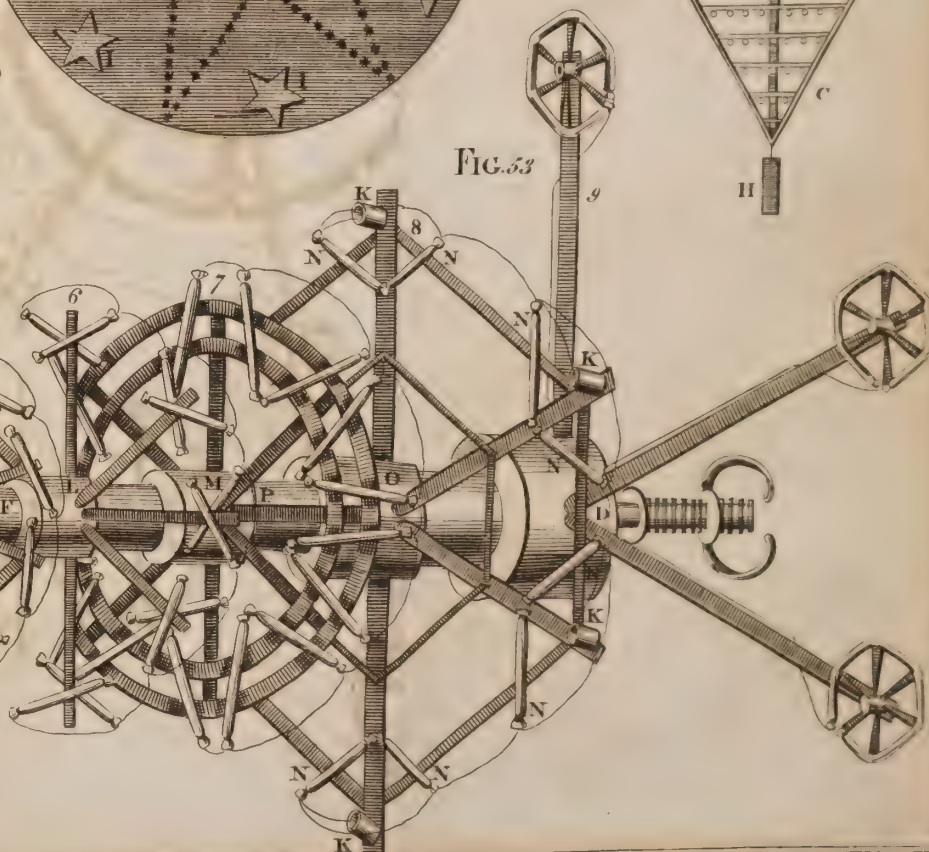
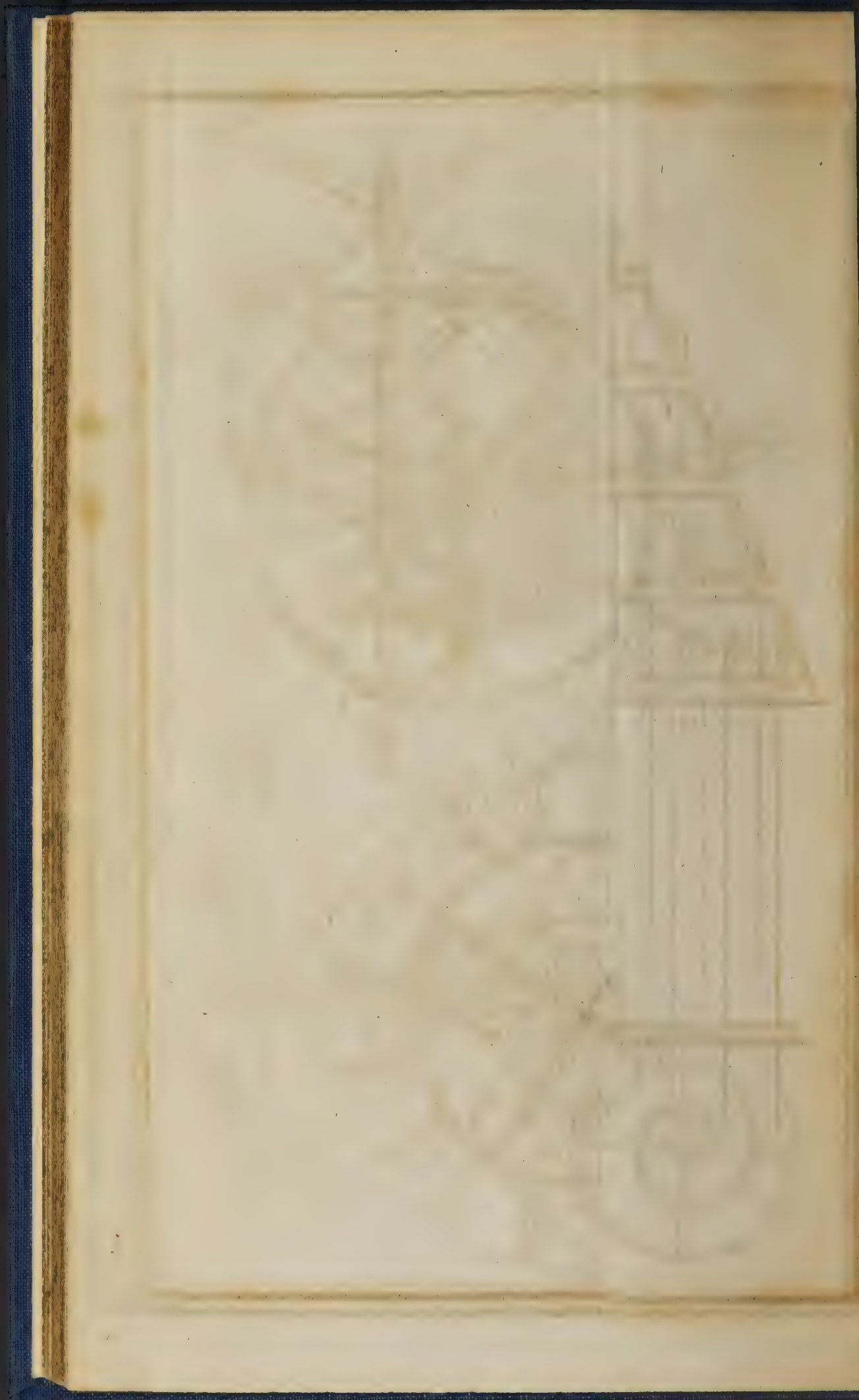
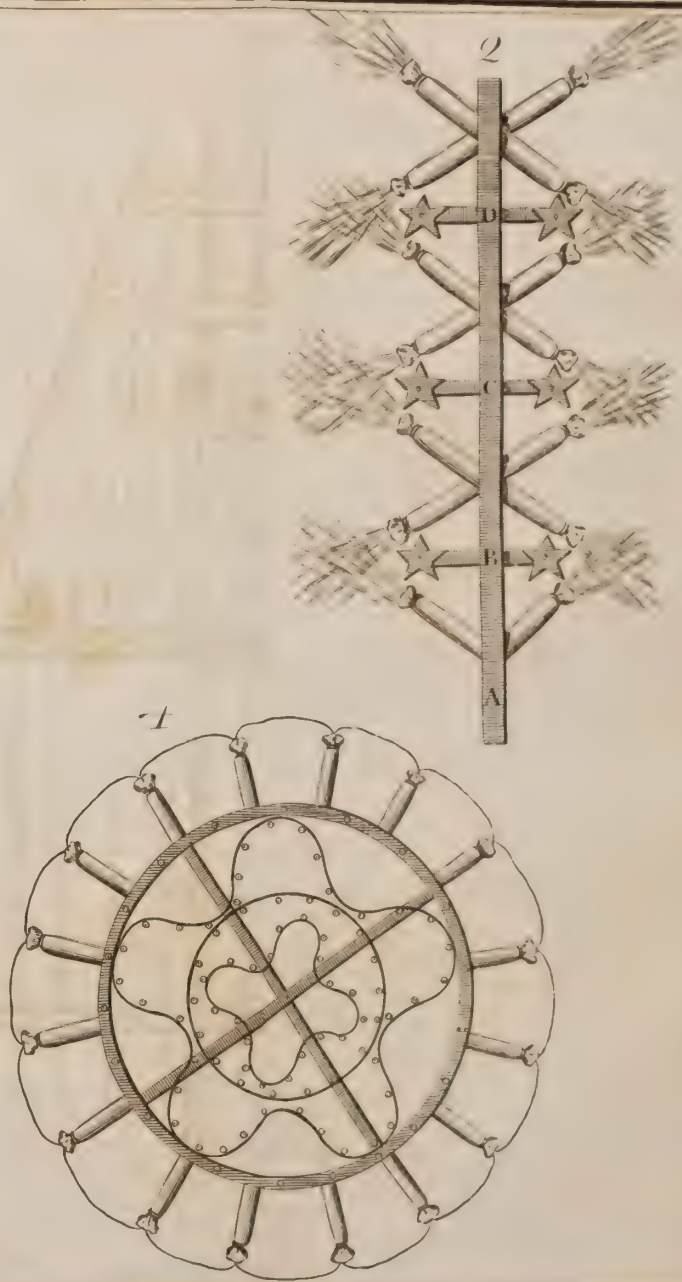
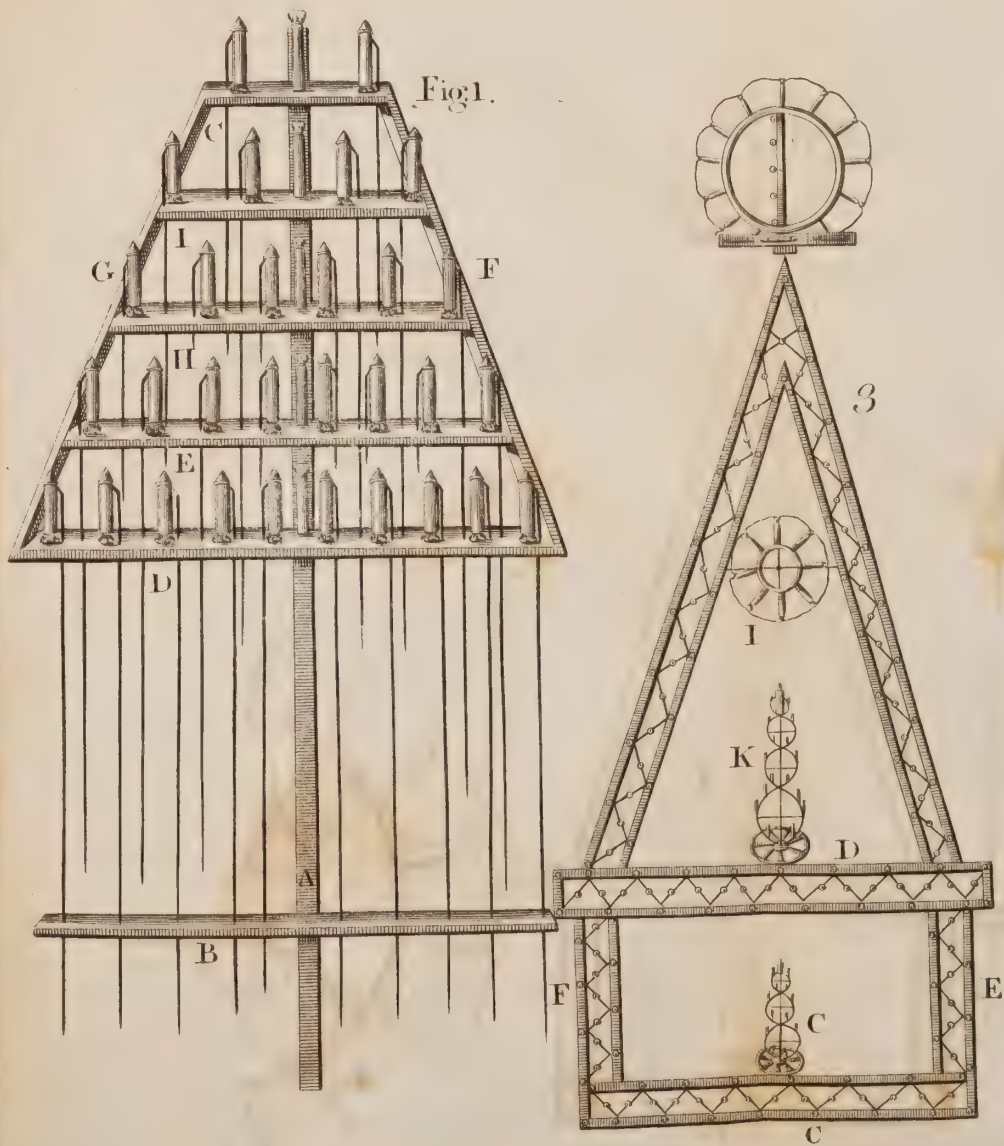
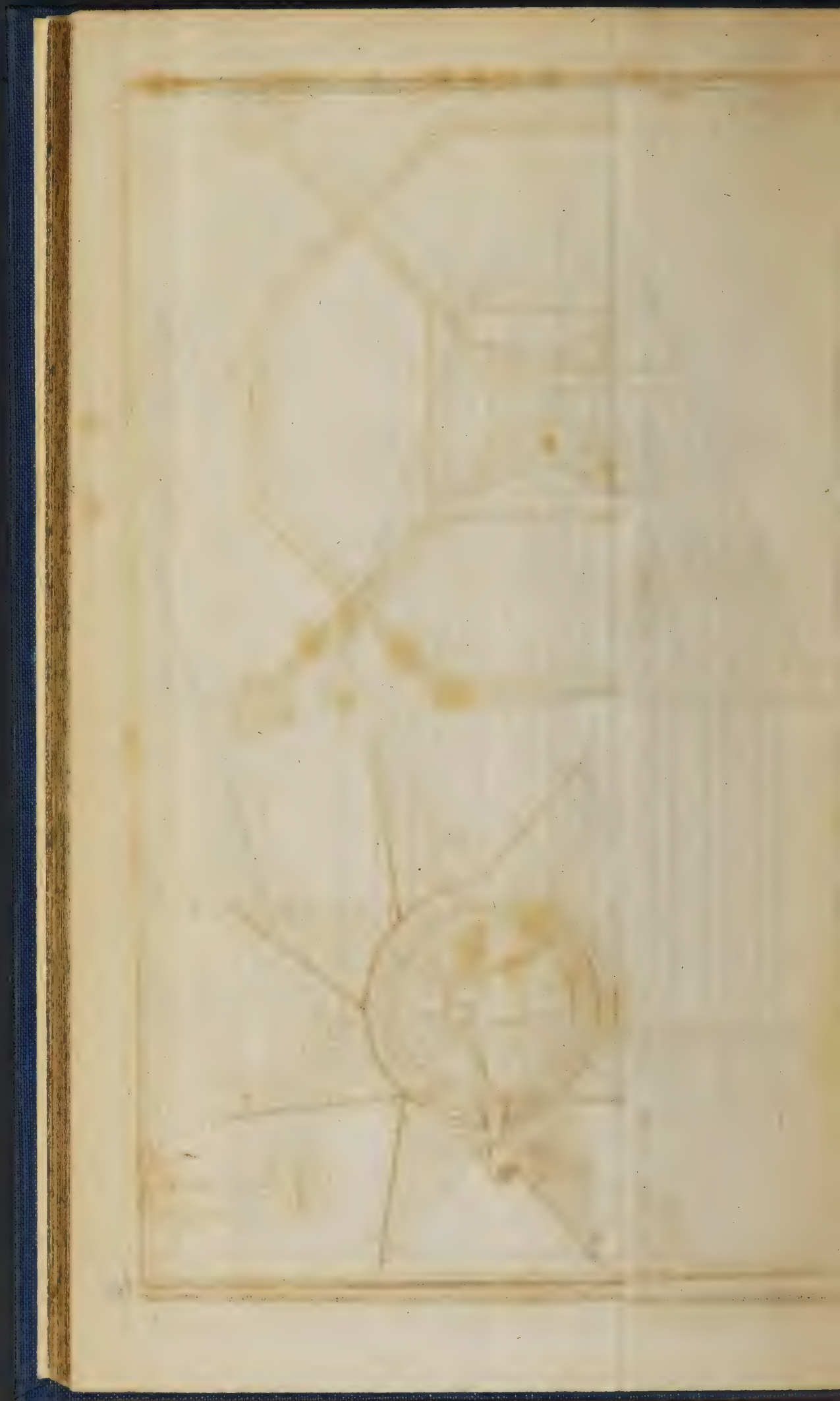


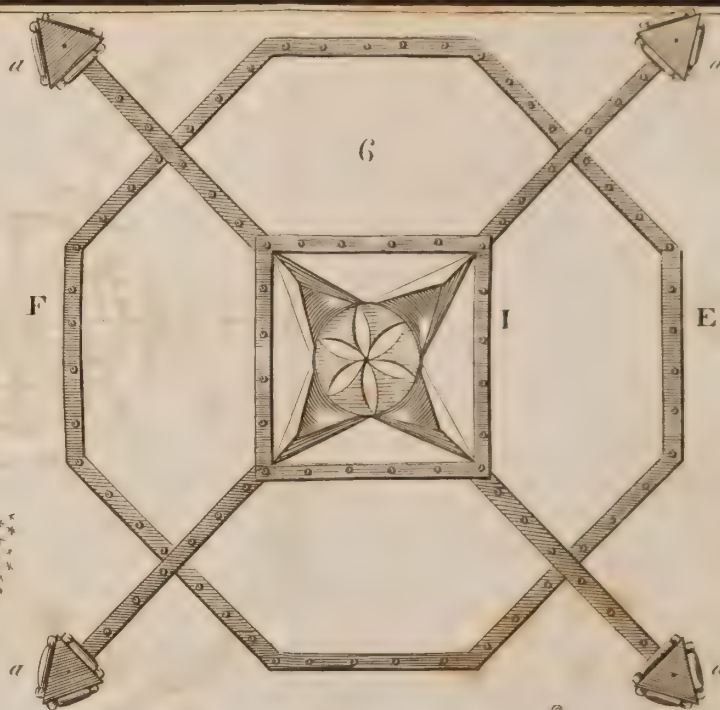
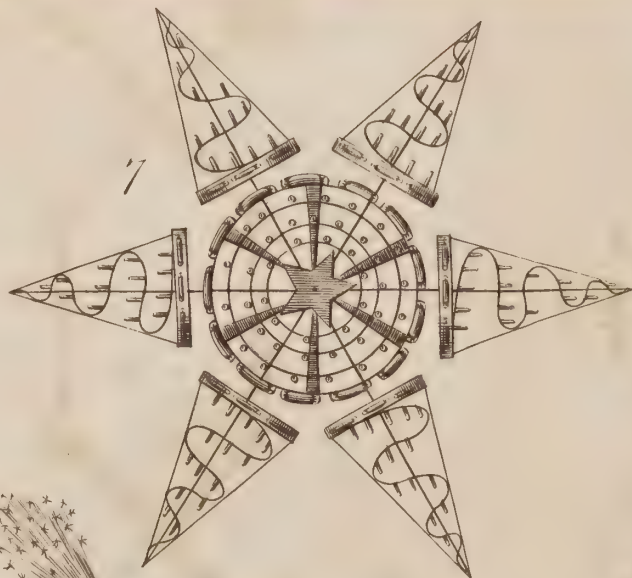
FIG. 53



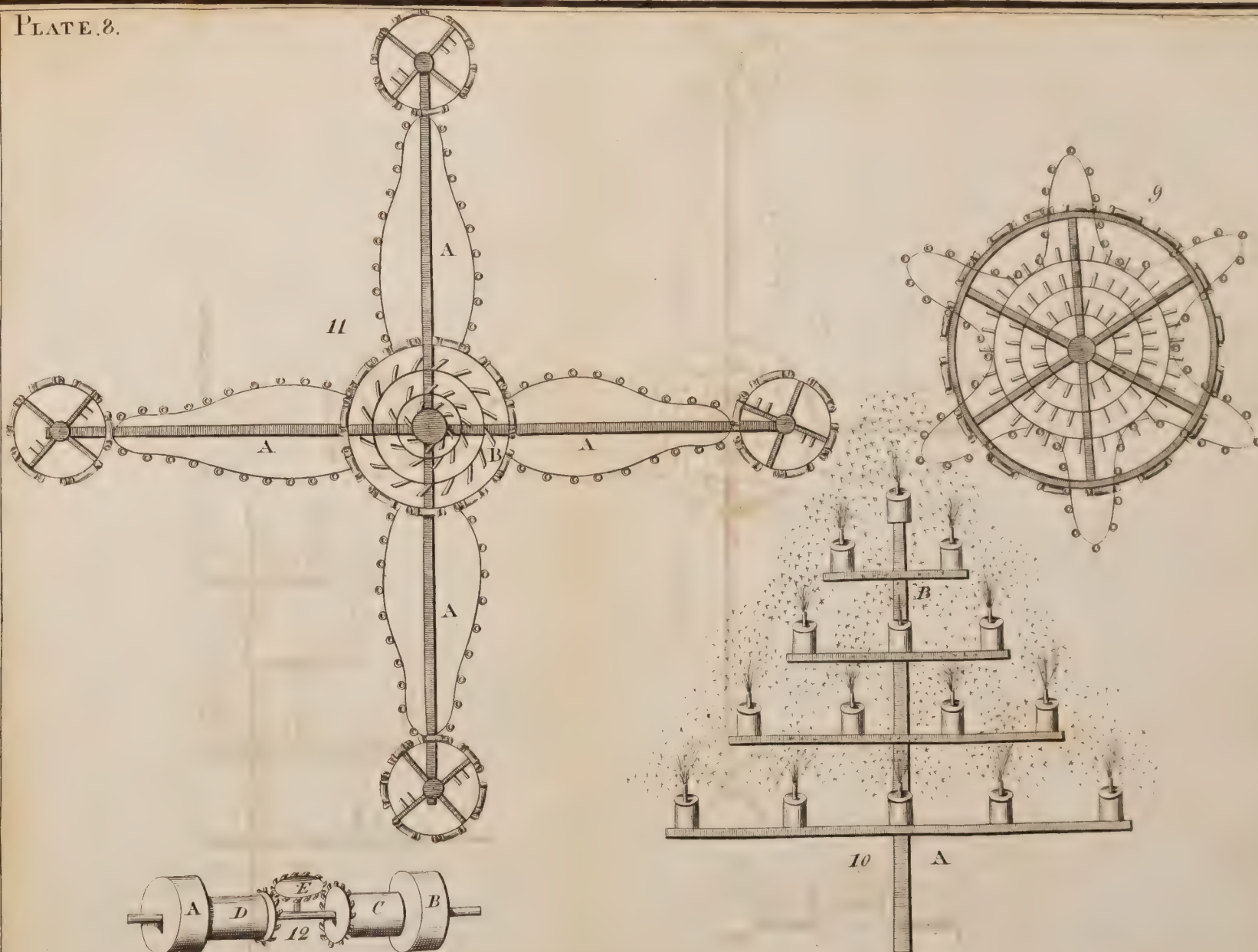














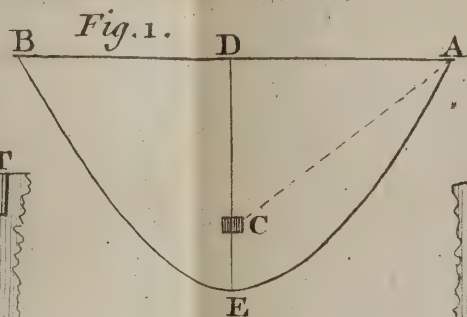


Fig. 1.

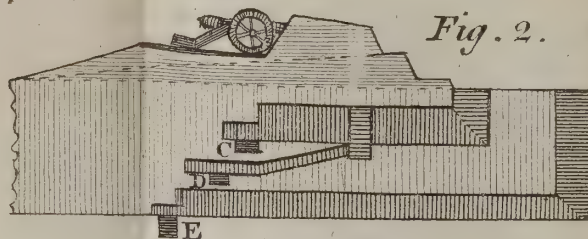


Fig. 2.

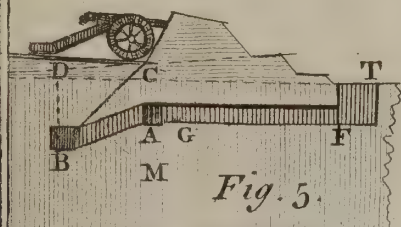


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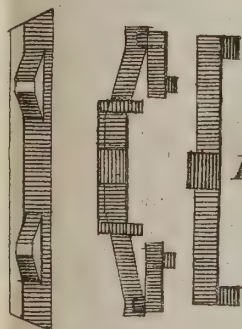


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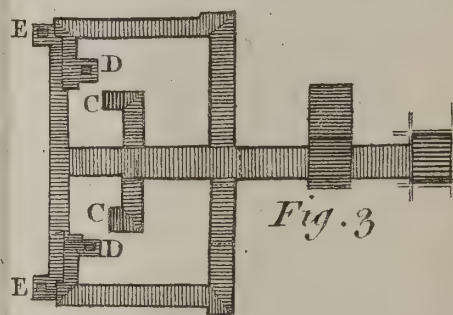
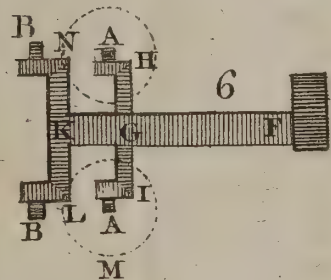


Fig. 3.



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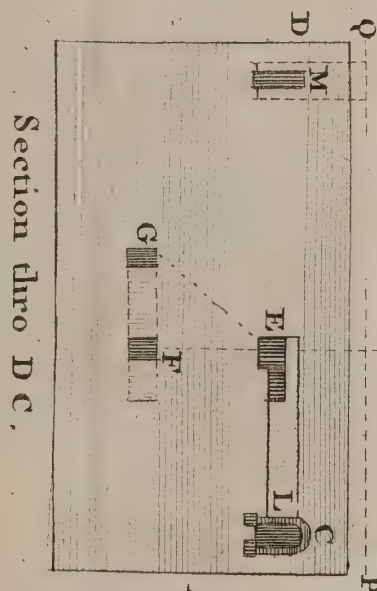


Fig. 9.

Section thro D C.

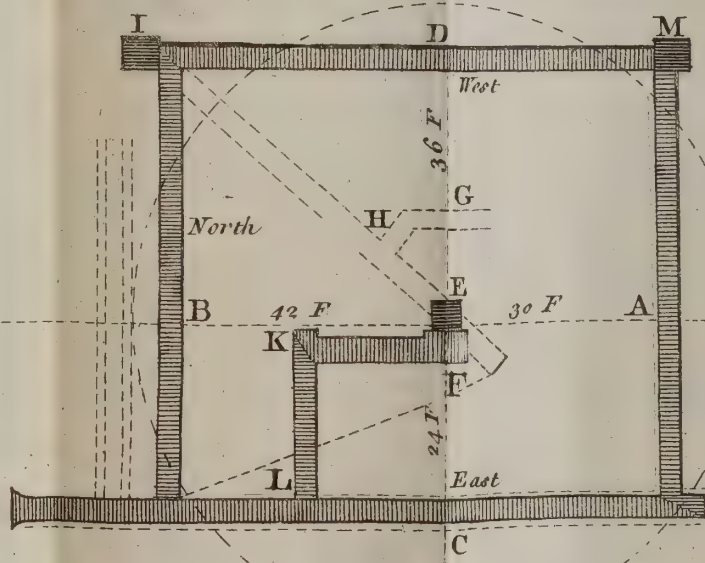


Fig. 7.

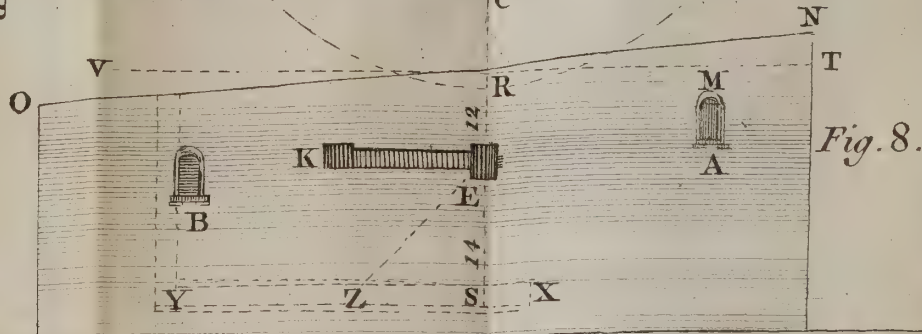
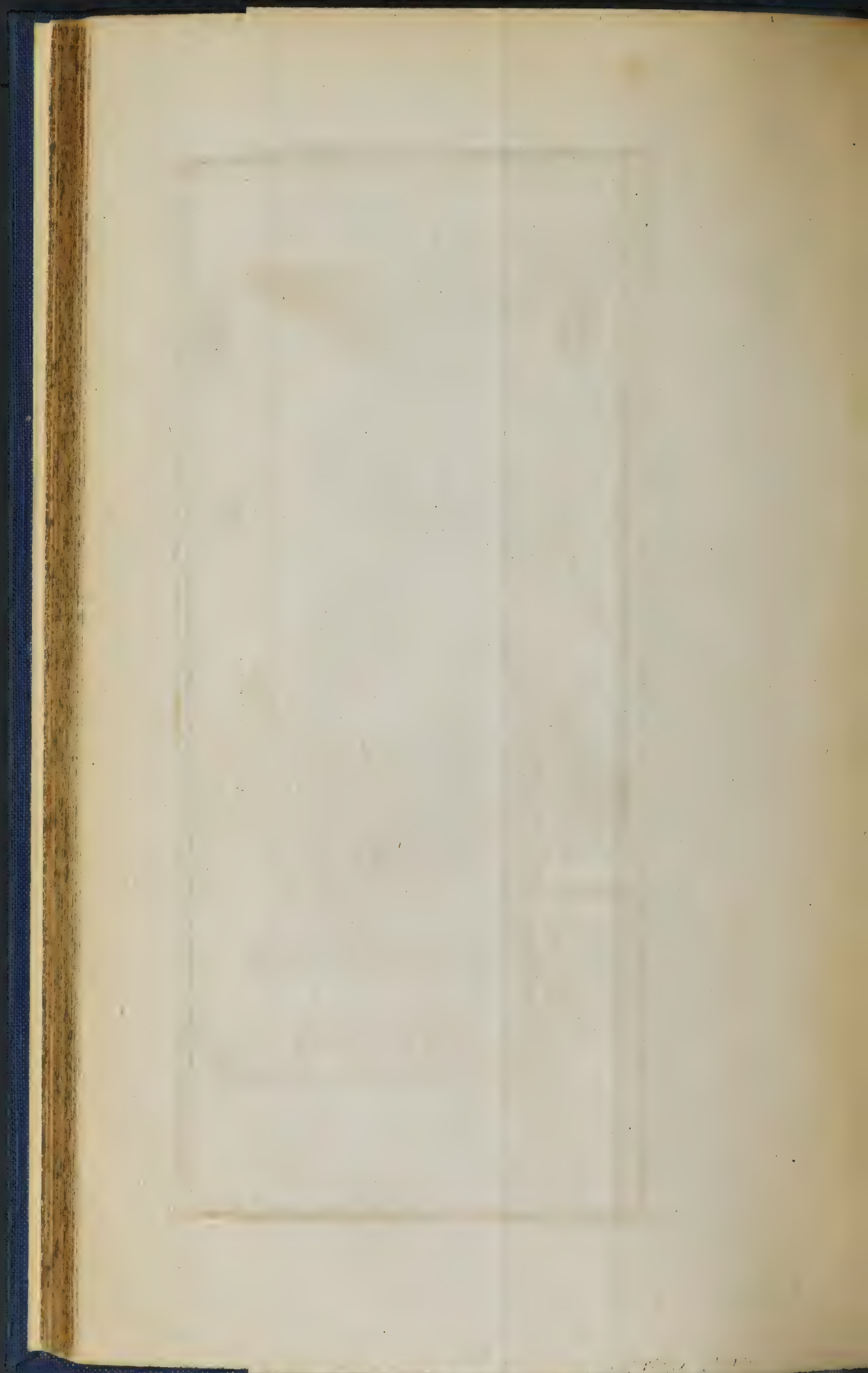


Fig. 8.



Profil thro C.D Fig. 7.

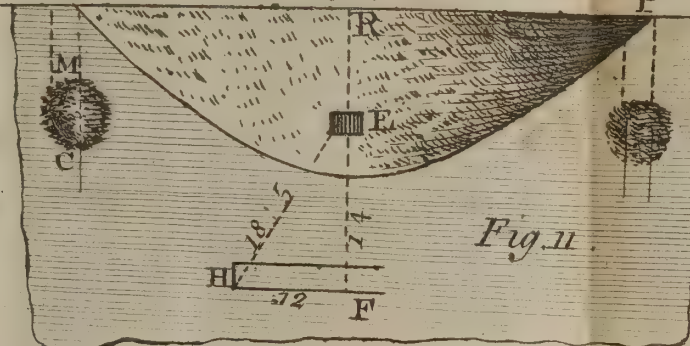


Fig. 11.

Profil thro A.B. Fig. 7.

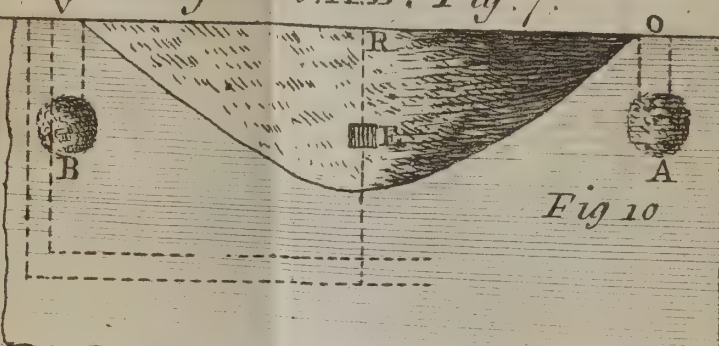


Fig 10

D. Place of Arms. 1. 2. 3. Majistral Gallery. 1. 4 and 3. 7. Travertering Galleries. 4. 7 Envelope Gallery. 5. 8. and 6. 9. Listners. C. B. Head of the Sap. A. B. C the Besieged Mines.

Fig. 14.

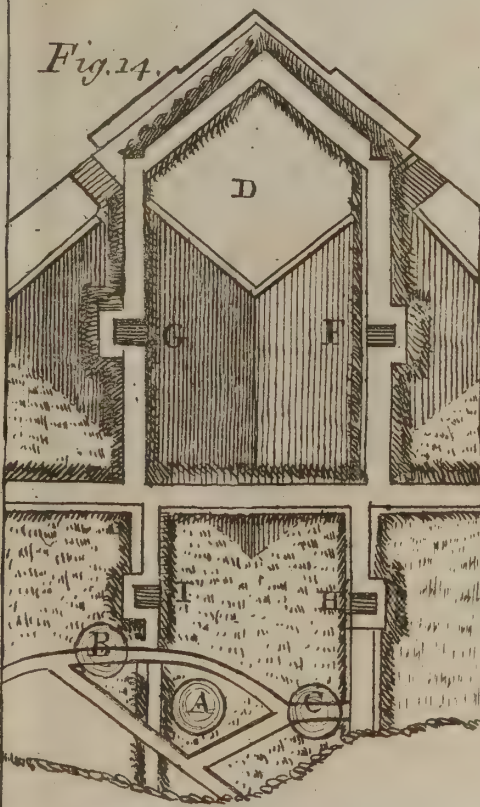


Fig. 13.

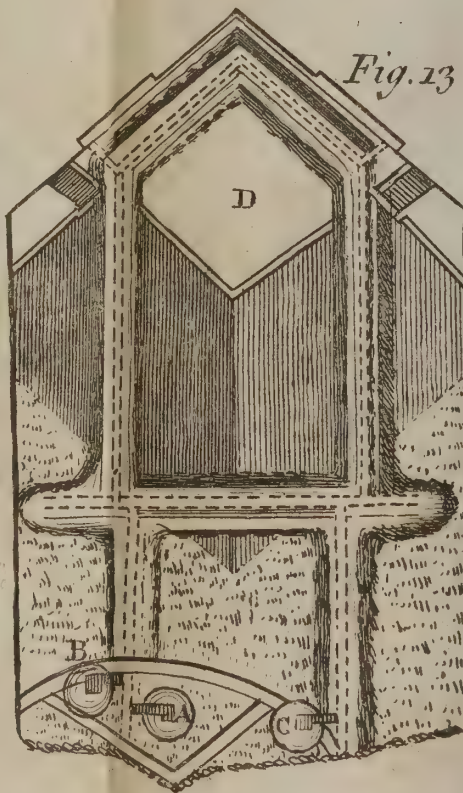


Fig. 12.

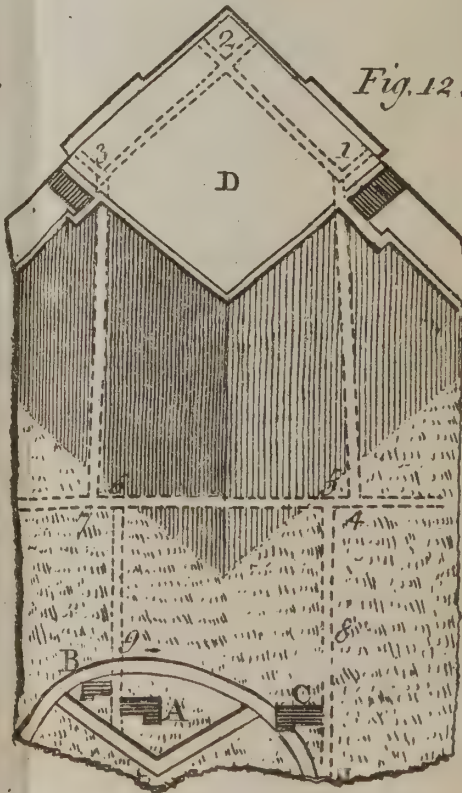
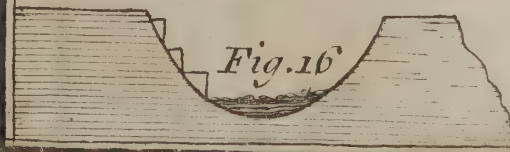


Fig. 16



Profils

Fig. 15



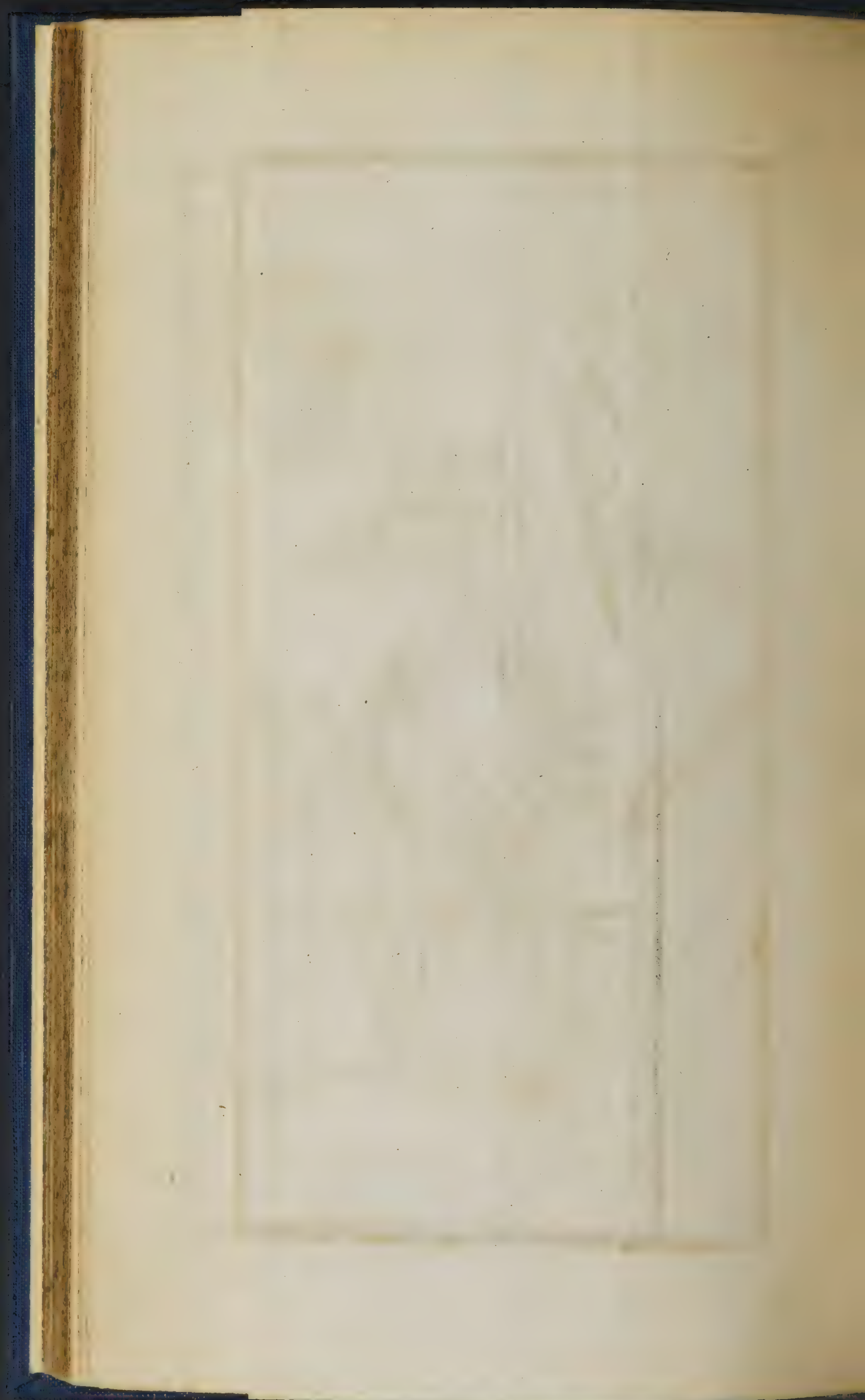


Fig. 19.

Profil parallel to the Covert way.

Profil perpendicular to the Covert way.

Fig. 18.

Fig. 17.

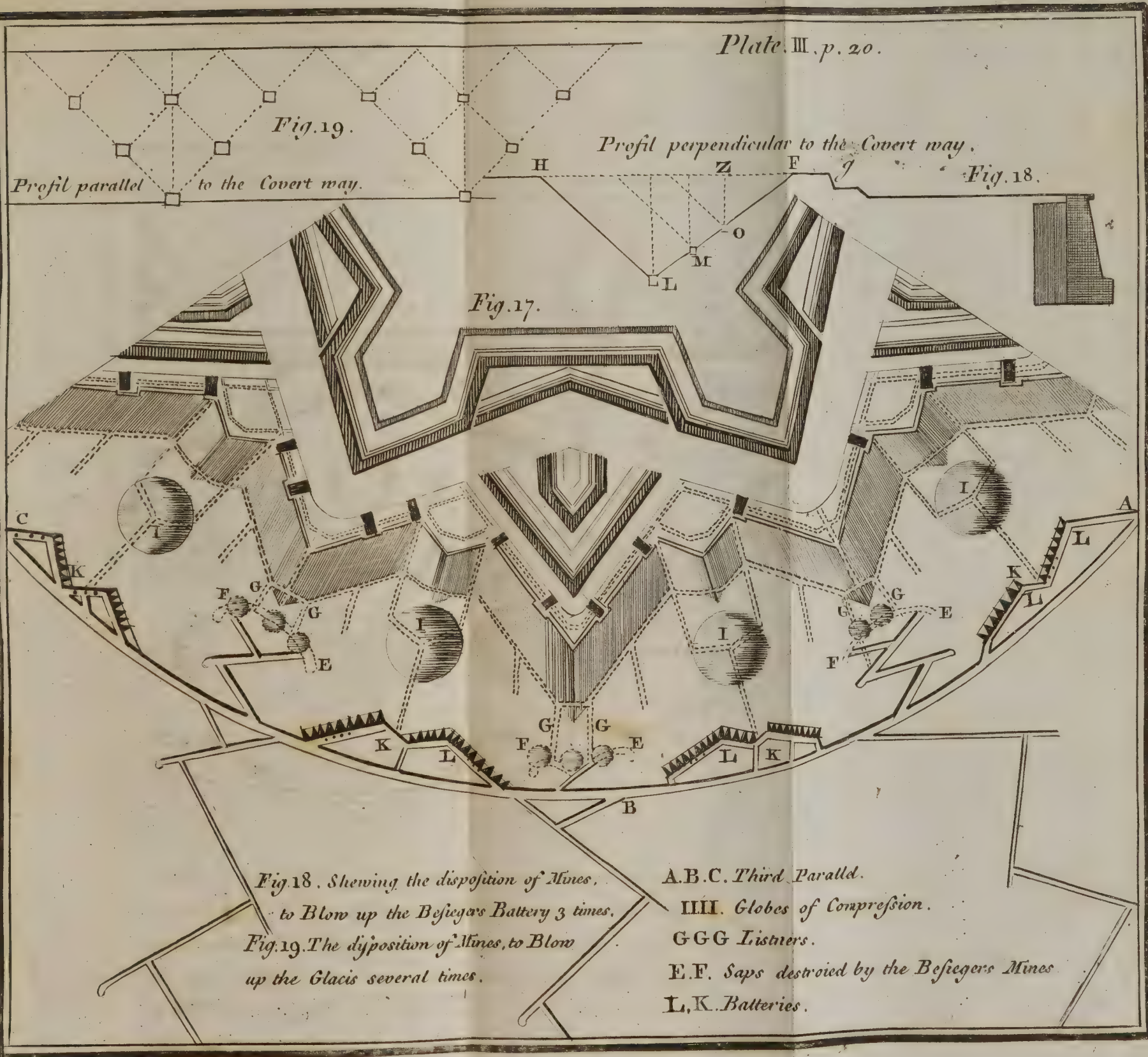


Fig. 18. Shewing the disposition of Mines,
to Blow up the Besiegers Battery 3 times.

Fig. 19. The disposition of Mines, to Blow
up the Glacis several times.

A.B.C. Third Parallels.

I.I.I.I. Globes of Compression.

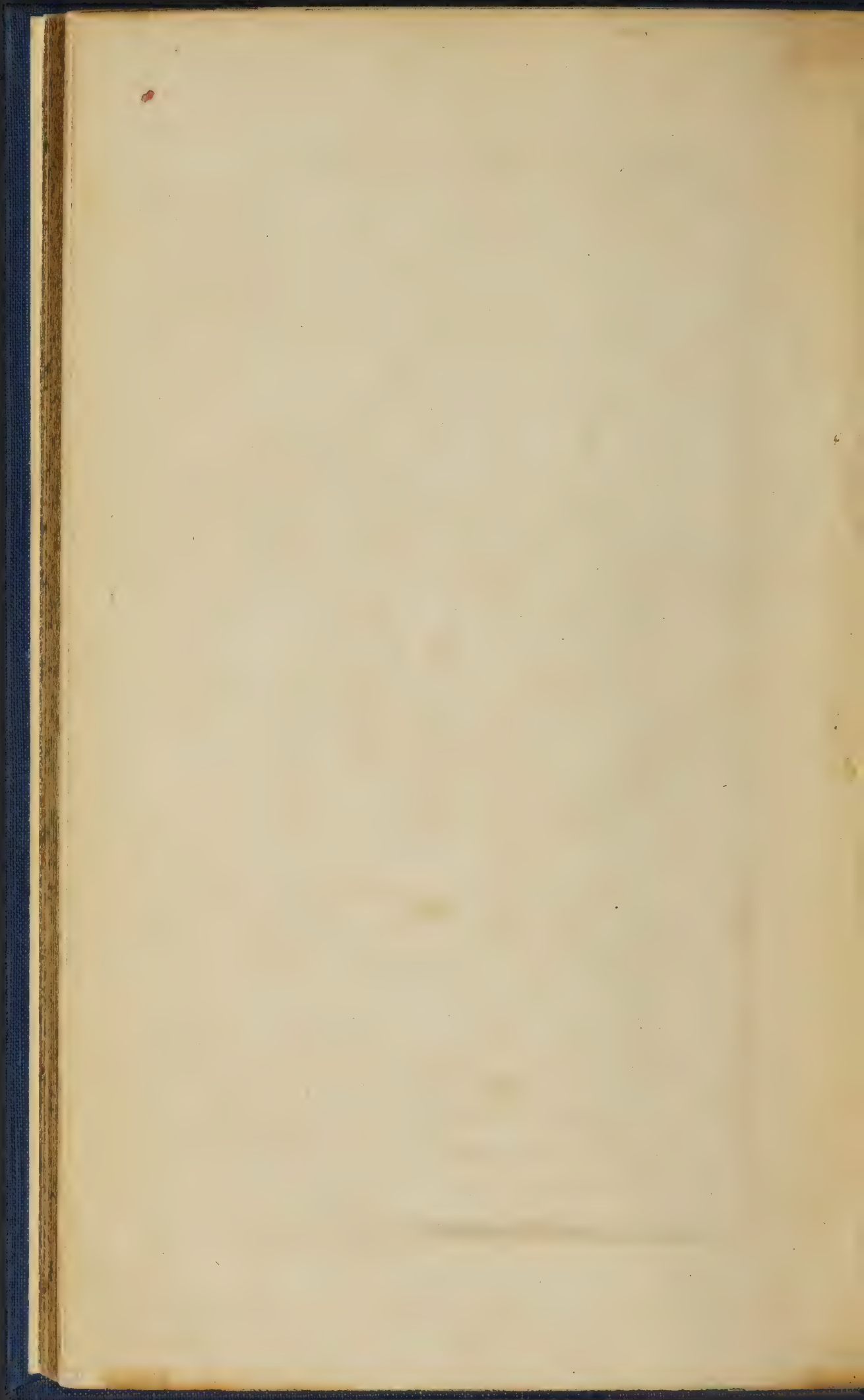
G.G.G. Listeners.

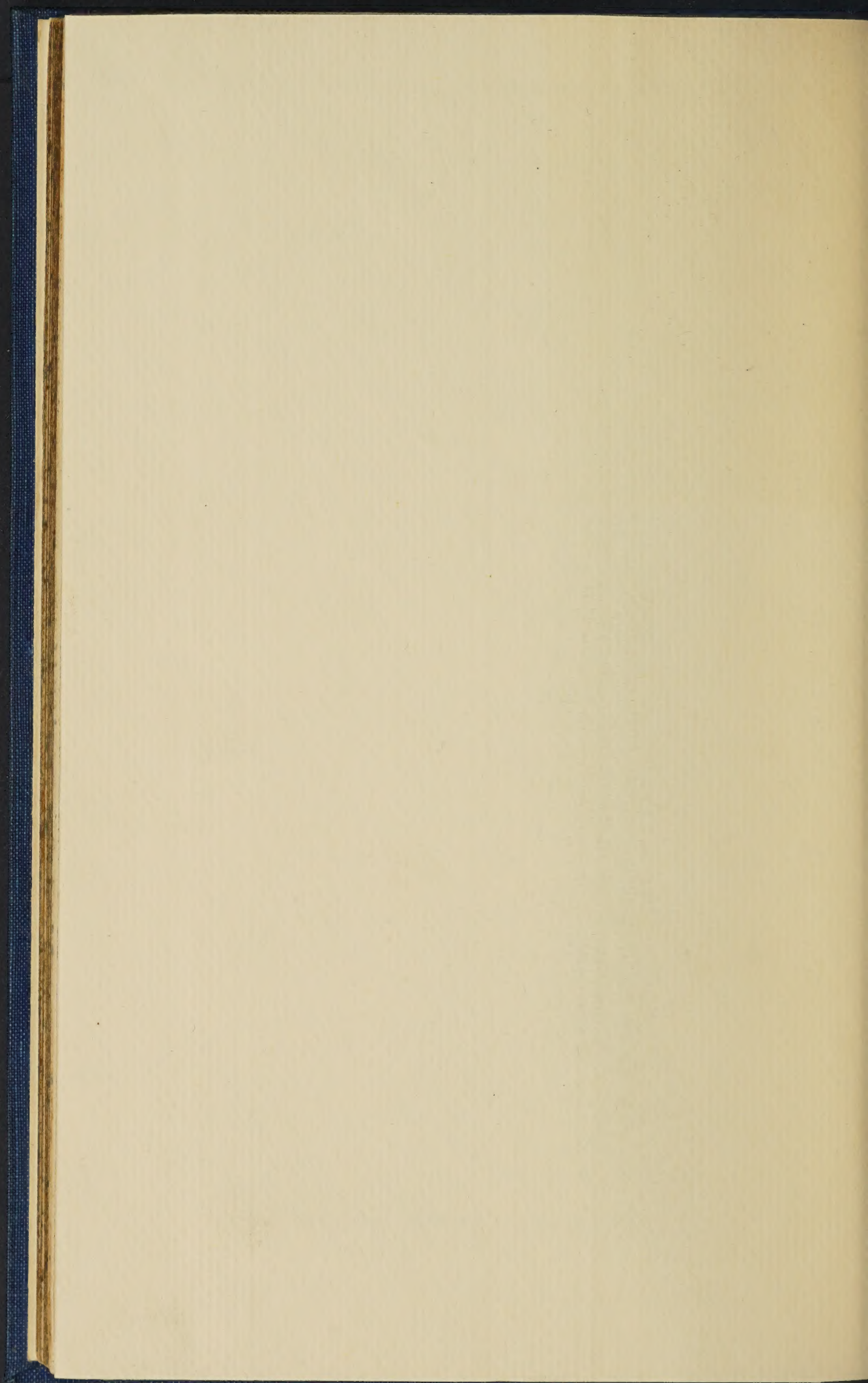
E.F. Saps destroyed by the Besiegers Mines

L.K. Batteries.

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